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AUTHOR LeBlanc, Maurice A.; Barker, Margaret R.
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ABSTRACT

A research study was conducted to investigate a control and display system for use with communication aids by physically disabled persons. A modification of a row/column scanning system was investigated to increase speed and accuracy of access to the communication system by six children with athetoid cerebral palsy. Four systems were compared: row/column directed scan (two switches); row/column auto scan (one switch); row auto scan (one switch); and column auto scan (one switch). Results revealed no significant differences among systems for scan time to select the correct target. The row/column auto scan (the most widely prescribed system for severely disabled persons) resulted in significantly more errors than any of the other three systems. It was also found that individuals who would have been or had already been prescribed a single switch system were able to operate two switches. (Author/CL)

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# FINAL REPORT

## September 15, 1981 - October 15, 1982

ED239470

Children's Hospital at Stanford
Palo Alto, California

# A COMPARATIVE STUDY OF CONTROL AND DISPLAY DESIGN PRINCIPLES WHICH AFFECT EFFICIENT USE OF COMMUNICATION AIDS BY THE SEVERELY PHYSICALLY DISABLED

EC161808

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**FINAL REPORT**
September 15, 1981 - October 15, 1982

Rehabilitation Engineering Center
Children's Hospital at Stanford
520 Willow Road
Palo Alto, California 94304
415/327-48800, x560

John R. Williams, Executive Director, CH@S
John J. Csongradi, M.D., Medical Director, REC
Maurice A. LeBlanc, Principal Investigator
Margaret R. Barker, Co-Principal Investigator

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## FORWARD

This project was a joint effort between the Rehabilitation Engineering Center, Children's Hospital at Stanford and Psycho-Linguistic Research Associates. Allen Dittman was the Office of Special Education Project Manager. Maurice LeBlanc, Principal Investigator, Director of Research, Children's Hospital at Stanford, directed the project. Margaret Barker, co-principal investigator, implemented the experimental design by coordinating with local schools and her own patient population, screening candidate subjects and administering the screening test and directing the data collection by the research assistants. Douglas Williams and Carol Simpson of Psycho-Linguistic Research Associates designed the experiment in detail and provided scientific expertise in the selection of stimuli, over-all guidance for the computer programming, and guidelines for the research assistants. PLRA analyzed the data, interpreted the results, and, together with Margaret Barker, prepared the text of this final report. The software was developed by Sol Katzman, a systems programmer and design engineer with extensive experience programming the TRS-80 microcomputer. Research assistants Becky Gordon, Tom Dominguez and Leslie Roberts worked with the subjects and operated the computer programs for screening and the experiment itself. The experimental sessions were conducted at the Rehabilitation Engineering Center at Children's Hospital at Stanford or at local schools depending on the ease of logistics for the subjects. The transportability of the TRS-80 computer made this flexibility possible.

ABSTRACT

Effective communication for the physically disabled individual relies on control and display system design. The systems currently available to individuals restricted to using single switch interfaces by their involuntary (athetoid) movements have limited use and are inadequate for communication. Frustration followed by rejection of these aids is widespread.

An observed difficulty is the inability of a user to reliably activate a time-dependent control and display system. It is possible that this group of physically disabled individuals could control devices more adequately with an appropriatly designed type of control and display system.

A controlled research study was conducted to investigate a modification of a row/column scanning system in order to increase the speed and accuracy with which communication aids can be accessed with one or two switches. A selection algorithm was developed and programmed in Basic to automatically select individuals with the characteristic difficulty in controlling time dependent control and display systems. Four systems were compared: 1) Row/Column Directed Scan (2 switches), 2) Row/Column Auto Scan (1 switch), 3) Row Auto Scan (1 switch), and 4) Column Auto Scan (1 switch). For this sample population, there were no significant differences among systems for scan time to select the correct target. The Row/Column Auto Scan system resulted in significantly more errors than any of the other three systems. Thus, the most widely prescribed system for severely physically disabled individuals turns out for this group with involuntary movement to have a higher error rate and no faster communication rate than three other systems that have been considered inappropriate for this group. We can now apply the information gathered during this study to assessment procedures and begin to develop theories on control of assistive devices for individuals with involuntary movements.

## BACKGROUND

This project addressed a question that was raised during the development of a versatile, portable, speech prosthesis (VPSP) for the severely disabled (LeBlanc, Simpson, Williams, and Lingel, 1980), which is a microprocessor based, wheelchair portable, speech prosthesis that can be controlled to speak and/or store any speech message desired by the user. Different control and display systems were provided for users with varying degrees of motor control: 1) 1-switch, row/column scanning; 2) joystick + selection switch or 5-slot controller and a user-driven cursor; 3) keyboard, direct selection. These control and display systems were chosen because they are typical of a wide range of commercially available communication and environmental control devices.

While communication speeds of 30 words per minute were obtained using the VPSP keyboard, experienced users could do no better than 4 WPM using the row-column scanning system, and users with cerebral palsy were considerably slower. Wethered (1976) found that individuals with cerebral palsy were slower using single switches than individuals with muscular dystrophy or multiple sclerosis, supporting what was found with the VPSP.

Commercially available communication and environmental control aids all use variations of three basic approaches to control and display systems which enable the user to indicate his or her intended elements or symbols of communication. These are scanning, encoding and direct selection. The approach that an individual uses is dependent upon that individual's physical and cognitive abilities. For an individual physically limited to the use of one or two switches or methods of indication, the approach used must involve scanning, although it may be combined with encoding in some cases. Methods of indication include controlled hand movement, head movement, eye blink, electrooculogram (EOG), electromyogram (EMG), and electroencephalogram (EEG).

> Scanning is
> "any technique (or aid) in which the selections are offered to the user by a person or display, and where the user selects the characters by responding to the person or display. Depending upon the aid, the user may respond by simply signaling when he sees the correct choice presented, or by actively directing an indicator (e.g.,light, arrow or cursor) toward the desired choice." (Vanderheiden and Harris-Vanderheiden, 1976).

Vanderheiden (in Vanderheiden and Grilley, 1976) indicated that scanning is extremely powerful because it can be used by individuals with minimal control (e.g. able to consistently make only one or two movements or signals). He also indicated that the power of the scanning technique is offset by slow speed of communication. The speed is slow because much time is spent passing over unwanted symbols before arriving at the desired symbol.

There are several types of scanning techniques, which include linear, row-column, and pseudo-scanning or step-scanning. The simplest technique,"linear-scan", presents the elements one at a time.

The desired choice is selected by responding or signaling when an indicator is directed toward it. This approach can be very slow. The more choices of elements that are to be presented, the slower the speed of communication becomes.

Linear scanning can be be accelerated by utilizing a two-speed scan. One switch controls the speed of the scan and the other stops the scan. The speed control switch increases the scanning rate. When this switch is released, the scanning returns to the slower rate. Vanderheiden indicated that "for some children, particularly athetoid children, this may not be within their capabilities and another approach may be more desirable." (Vanderheiden, 1976)

In row-column scanning, choices are arranged in a matrix-like display (refer to figure 1). Elements of the matrix are indicated sequentially by moving a cursor or by illuminating a light next to them. Row-column scanning enables the user of the aid to select first the row that the desired element is in and then to select the column using a single switch.

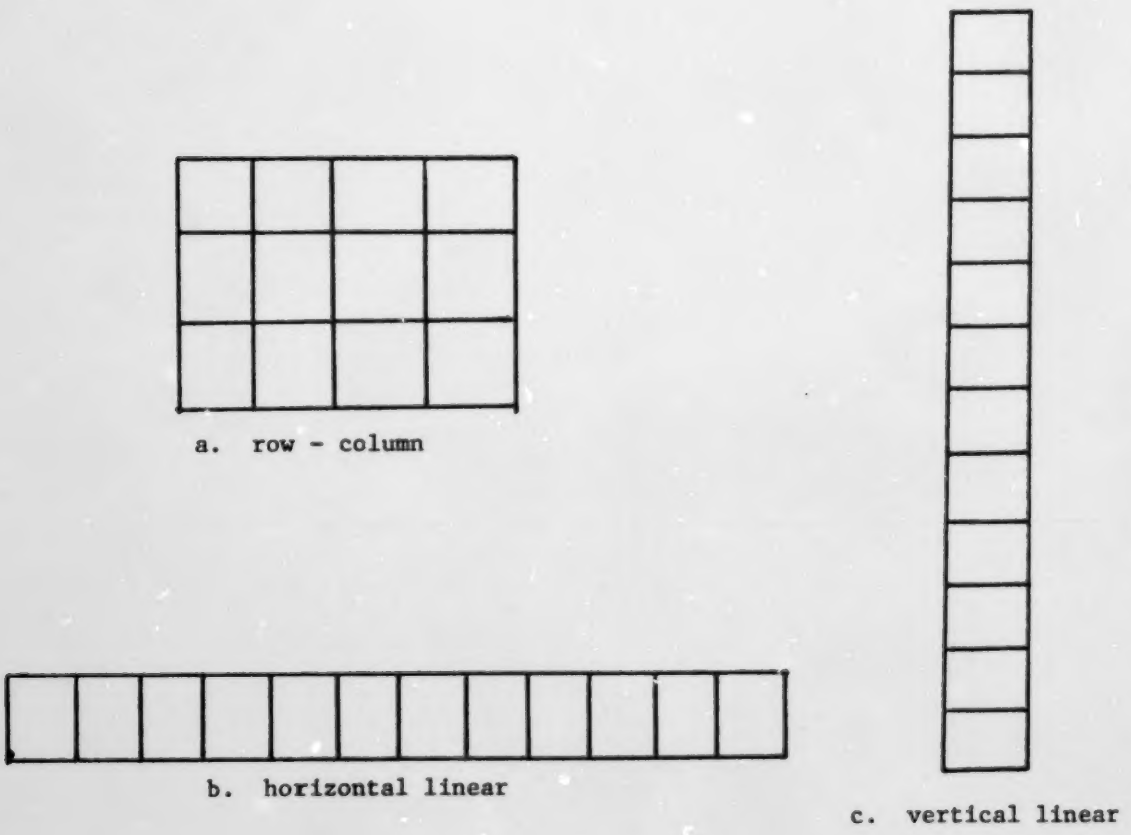
Pseudo-scanning or the "step-scan", (Vanderheiden, 1976) is a technique in which the user actuates a switch to move the indicator from one position to the next. Vanderheiden pointed out that this is not a true scanning technique because the aid does not actively present choices and wait for a response but that the user actually moves the indicator. Logically, this is a "directed" scan, in that the user directs the movement of the indicator.

During the user evaluation phase of our VPSP project, it was observed that those individuals with athetoid cerebral palsy who had much involuntary movement could not reliably activate the switch when the moving cursor arrived at the desired item. This problem manifested itself regardless of the scanning speed selected by the user, with the slowest available speed being one cursor movement per 6 sec. When the VPSP was at their disposal for a full week, at home, school, and/or hospital, no measurable improvement in accuracy was recorded. Speech therapists involved in the project reported similar problems with devices that use the row/column scanning system. Yet, devices with this control system continue to be prescribed for non-vocal individuals with involuntary movements. And, apparently taking their cue from existing devices, designers of new, microprossessor based systems for the severely physically handicapped are using the row/column scanning system, for example, Bruey, 1980.

It was also noted during the evaluation of the VPSP that all of the users who had the previously described problems with row/column scanning independently developed the same alternative method of controlling the device. They would elect to operate the VPSP in "Verify On" mode. This means that the cursor, upon having the item next to it "selected" by the user, would flash momentarily while the system was in a "wait" mode. During this time interval, the user could hit the "selection switch" again to cancel the selection, in case it had been unintended. Then the cursor would move to the next item in the row or column being scanned. If, however, the selection made was desired, the user simply waited for the cursor to stop

flashing. Then the system would act on the selected item. (The alternative to Verify On was "Verify Off"; in this mode, the system acted on the user's selection as soon as the selection switch was pressed, with no provision for cancel.) The users in our study, however, used the logic of the "Verify On" mode to step the cursor to the item they wanted rather than letting the system scan the cursor there automatically. They pressed their selection switch twice for each item they did not want, to drive the cursor on to the next item. When they got the cursor to the item they wanted, they tried (not always successfully) to break their motor pattern of two successive switch presses and instead to hit the switch just once and then pull back from the switch to let the flashing cursor time out and thus cause the system to act on their selection. If these users are representative of the severely athetoid group, then an alternative type of control and display system might work more effectively for the whole group.

Figure 1. Scanning Schemes



a. row - column

b. horizontal linear

c. vertical linear

## APPROACH

Our purpose was to study the ability of persons with athetoid cerebral palsy to control a two-switch, user-driven cursor, row/column scanning system. The underlying assumptions made were 1) That "1-switch" users will actually be able to control some other, second switch. (This assumption is supported by the observation that all users of the 1-switch VPSP were able to deal with two switches, the on/off switch and the selection switch); and 2) That those with severe athetosis who are 1-switch users would, as a group, be able to perform the regular, successive switch activation which was successfully used by the VPSP operators.

An interface consisting of two switches utilized this behavior. One switch, the "scanning switch", moved the cursor when it was actuated (speed of cursor movement was adjustable for each user). Note that the scanning switch functioned in two modes. When it was held down, it caused the cursor to scan; but if given a single actuation and released, the cursor advanced one position only. This switch was used to position the cursor on the desired item - one of the rows or an item within a row. The second switch was the "selection switch", which "selects" the item next to the cursor. If the selected item is a row to be scanned, then the act of selecting it causes the cursor to move across the row when the user next activates the scanning switch. If the selected item is an item in one of the rows, then the act of selecting it transfers the selected item to a holding space (where the user would construct sentences for viewing, printing or speaking in a complete prosthesis system.) When neither switch is pressed, the system does nothing, allowing the user to rest, think, or whatever. Note that this system is similar to the step scanning system discussed above.

Our principle goal was to determine whether the alternative user-driven cursor, 2-switch system is any more effective for the target population than is the currently used row/column scanning system. Simpler scanning systems were also studied so as to isolate the effect, if any, of the two-dimensional feature of row/column scanning systems apart from their scanning feature. The experiment was designed to also obtain data on learning trends for the four types of systems and to shed some light on the underlying cause of the observed difficulty, i.e. whether it is the result of lack of experience with motor control in the dimensions of time and space or whether it results from inability to deal with two-dimensional displays (a possiblity suggested by Judy Montgomery in a talk to the Bay Area Non-Oral Communication Group, June, 1980). We compared response time and accuracy performance for four types of systems (refer to Figure 1): 1. the traditional row/column scanning system, 2. the proposed user-driven cursor, 2-switch system, 3. a one-dimensional, linear (vertical column) scan system, 4. a one-dimensional, linear (horizontal row) scan system. Data were collected over a sufficiently long period of time to observe learning curves on each system, as well.

Clearly there are other possible systems that could have served as experimental controls for the proposed system. Financial limits, however, restricted the number of experimental variables and the number of levels for each of those variables that could be properly studied. We believed it was important to include systems that are representative of those already in use and commercially available and which differ by a minimum number of features from the proposed system and from the traditional row/column scanning system. Both of the simpler scanning systems, vertical and horizontal, meet these criteria. See Table 1 for a feature analysis of the four systems to be compared.

| | FEATURE | | |
|---|---|---|---|
| SYSTEM | SCANNING | VERTICAL | HORIZONTAL |
| ROW/COL SCANNING | AUTO | YES | YES |
| 2-SWITCH DIRECTED | DIRECTED | YES | YES |
| ROW SCANNING | AUTO | NO | YES |
| COLUMN SCANNING | AUTO | YES | NO |

TABLE 1: FEATURES OF FOUR CONTROL AND DISPLAY SYSTEMS

## METHOD

### Candidate Subjects

A large group of individuals with severe athetoid cerebral palsy who are non-vocal or have severe dysarthria have been provided other types of assistive devices by the Rehabilitation Engineering Center (REC) of Children's Hospital at Stanford (CH@S). From this group and from individuals referred by cooperating schools we selected volunteers for this study and from the larger group chose a group of six for intensive study who had the following characteristics in common: 1. Severe athetosis. 2. Cognitive ability to recognize the letters used and to follow the directions given. 3. Demonstrated by their performance on the following screening test that they have difficulty selecting a target using the row/column scanning system and that they have a high probability of erroneously selecting the item just before or just after the target, i.e. display the behavior pattern observed for the VPSP evaluation users.

### Screening Test

The purpose of the screening test was to select only those individuals who are neither extremely accurate nor random in their operation of a row/column scanning display and control system. Included in the study are only those individuals who are like the VPSP users that we observed erroneously selecting the item just before or just after the one they wanted. We refer to the volunteers who took the screening test as "candidates". Those who were selected by the screening test (and the other three criteria above) became the subjects for the extended study.

The screening test consisted of from 3 to 6 trials, with the number of trials determined by the candidate's performance as the test progressed. The task for each trial was to use the "select" switch to select a target item, a letter of the alphabet, presented by the computer. Only the first response on each trial was recorded for test purposes. Each wrong response was recorded in terms of its distance in the scan in front of or after the target. So, -1 means the item in the scan just before the target was erroneously selected; 0 means the target was accurately selected; +3 means the item 3 items after the target was selected. The probability of someone whose switch-actuation behavior is completely random selecting any one letter from an array of 12 letters is 0.0833. Thus, the chance of three such selections being made in three trials by such an individual is 0.00057. This was our criterion for accurate performance; if an individual selected the target letter three times, he was judged not impaired enough to qualify for this study. If he made three +1 or -1 errors ($p = 0.0046$), then the candidate was judged to have the requisite athetoid behavior and comprehension of the task to participate in the study. If, after three trials, neither 3 target selections nor 3 +1 or -1 errors had occurred, the testing was continued up to a maximum of 6 trials. The probability of selecting by chance the letters either side of the target 3 or more times out of six trials is 0.0044. Thus by extending the number of trials to 6, we were unlikely to accidentally include anyone whose target selection

behavior was random. If at any point during the screening test the candidate accumulated 3 of the +1 or -1 type errors, that individual qualified as one of the subjects for the study and this concluded the screening test. If the screening extended to 6 trials, then a candidate had to score 5 correct out of 6 in order to be judged as too accurate to benefit from our alternative system. This 17% error rate criterion is based on our calculations of lost time due to erroneous sections made with a 5 x 5 size row/column scanning system, assuming a cursor scan rate of 1 item per 0.5 seconds. With any error rate greater than 17%, the time lost due to errors becomes increasingly greater than the error rate. For example, with an error rate of 50%, the time lost is 87% of the time taken to spell a 5-letter word making an increase of 87% in the time per word communicated. If at the end of 6 trials, 3 or more of the responses were of the -1, 0, or +1 type, with the condition that 2 of the 3 be of the -1 or +1 type ($p = 0.0033$), the candidate was included as a subject in the study. If any other pattern of responses resulted, the candidate was not selected, since a variety of other problems, such as inability to find the target visually, could be present. (Such problems are also important but are simply beyond the scope of this proposal.)

Subjects

During the screening, individuals demonstrating all the above different types of behavior were discovered. Many children diagnosed as athetoid CP had learned to use reflexive movements to their advantage and had thus adapted so that they could effectively use a switch. Some of the candidates had difficulty understanding the task. For some, the concept of a scanning system was new and/or they had no previous exposure to electronic aids. Also, we believe that some of the teachers in the schools who recommended certain candidates to us did not actually understand or had not previously identified the particular type of problem we were studying; thus not all the children screened were really good candidates and, conversely, we may have missed some children who do indeed have difficulty making reliable time-dependent movements. Of the 39 candidate subjects who participated in the screening process, 18 were too accurate, 15 displayed neither the too accurate nor the high rate of +1 and -1 type of errors. The remaining 6 candidates were selected by the algorithm as having the behavior of interest to this study. Table 2 shows the characteristics of the six subjects in terms of age, diagnosis, and current communication device, if any.

Equipment

A TRS-80 Microcomputer was purchased for this project, and programmed to handle all stimulus presentation, response timing and accuracy measures, and some of the data reduction. This equipment saved significant experimenter time and ensured accurate data recording. The TRS-80 is widely used in educational applications at this time, thus increasing the potential number of users for programs developed for it. Suitable single and double switches were identified by the Children's Hospital at Stanford Rehabilitation Engineering Center to provide each child with a switch he or she could activate as reliably and accurately as possible, by whatever

method was most effective. Actuation means included head motion, head stick, hands, feet, or gross limb movement. The computer was programmed to present an easily-taught and understood letter selection task on the CRT screen. Twelve letters of the alphabet were chosen for their visual disimilarity, as determined from grapheme confusion matix data in the published literature (Kinney, Marsetta, and Showman, 1966). These letters were displayed on the screen in a row/column matrix, a single row, or a single column, as appropriate for the experimental condition (Figure 2). The computer was programmed to drive the cursor in a row-column scan under computer control, a row- column scan under subject control, and two types of linear scan (vertical and horizontal) under computer control. It was also programmed to accept subject switch closures, properly de-bounce the signal, and make appropriate changes to the screen display as determined by the switch selections made by the subjects. The programs to accomplish much of this made use of algorithms implemented in software developed for the Versatile Portable Speech Prosthesis. Implementation of these algorithms to provide a test and evaluation package on a widely-available computer (Radio Shack TRS-80) is a significant benefit of this project, and it is anticipated that at the conclusion of this project, this software will be made available for diagnosis of children and evaluation of switches and appropriate control/display systems for individual users and for computer assisted instruction applications.

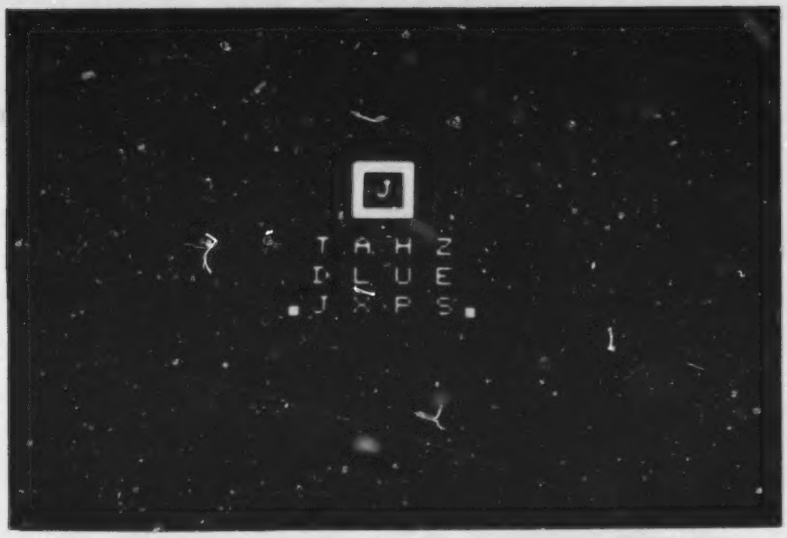
Experimental Design

Each of the six subjects used each of the four systems, one at a time. The order of systems used was balanced across subjects to control for transfer effects. A given subject used a system approximately every other day, except weekends, for approximately 2 hours per day. The first day consisted of familiarization with the system to reduce the effects of learning. Each subsequent day with that system included some refamiliarization time. Each day contained 3 runs of 12 trials each. Between runs, subjects rested and relaxed, as they wished. The task for each trial was to select a "target" letter (which was shown on a special area of the CRT) from the row-column (scanning or subject-driven) or linear array displayed on the CRT. Each of the twelve letters was presented an equal number of times within each run, in random order. A subject used the same system for 3 days for a total of 9 runs with that system. The procedure was then repeated with the next system until that subject had used all four systems. All runs with a given system were in succession to provide for subject familiarization with a given system and so that learning could be detected.

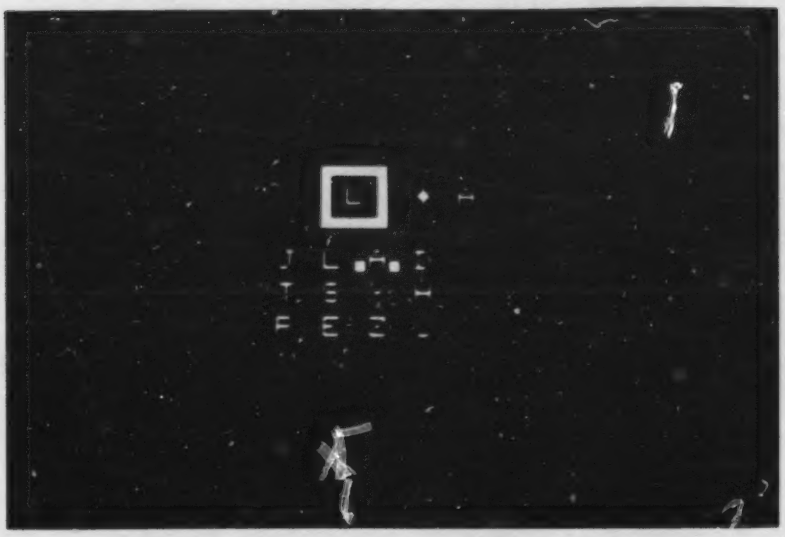
Data collected consisted of two types of response time, measured from onset of the target stimulus display on the CRT to time of accurate response selection. Elapsed time was defined as the total elapsed time from the initial presentation of the target to the subject's correct selection of the target or sixth miss (erroneous selection for a given target). Included in the elapsed time, in cases where the subject had one or more misses before getting the correct selection, was time between "tries" when the subject might have some physical reason to not be ready to start the

| Subj. #, Sex | Age | Diagnosis | Current Communication Method | Elec. | Selection | Scanning Control |
|---|---|---|---|---|---|---|
| 1,F | 14 | Athetoid CP | ETRAN and eyes left and right for yes and no answers to questions | none | Zygo lever left side of head | Zygo lever right side of head |
| 2,F | 18 | Athetoid CP | Speech unintelligible except to friends; no written method | none | Right hand pressing Zygo tread switch on table | Left hand pressing Zygo tread switch on table |
| 3,M | 14 | Athetoid CP | Some speech, nods for yes/no, some typing with many errors | joy-stick on elec. w/c | Zygo tread switch on laptray (L. hand) | Zygo tread switch on laptray (R. hand) |
| 4,F | 20 | Athetoid CP | Nods head for yes/no; eyegaze at wordbook | none | Zygo tread switch on L. side of headrest | Zygo tread switch on R. side of headrest |
| 5,M | 18 | Athetoid CP Severe Scoliosis | Yes/no by looking at chair arms; "yes" and "no" written on w/c arms | none | Zygo tread switch on L. side of headrest | Zygo tread switch on R. side of headrest |
| 6,M | 18 | Athetoid CP | Speech unintelligible except to friends; Blissboard, with difficulty due to inaccurate pointing | joy-stick on elec. w/c | L. hand on Zygo tread switch on laptray | R. hand on Zygo tread switch on laptray |

TABLE 2.
CHARACTERISTICS OF SUBJECTS



a. Row column scanning system, row indicated by cursors.



b. User driven cursor, 2-switch system. Letter "a" indicated by cursors.

Figure 2. Photographs of displays on the TRS-80 Mode III Monitor for each of the four types of systems. The "target" letter is displayed in the box.

c. Row scanning. Letter "s" indicated by cursors.

d. Column scanning. Letter "h" indicated by cursors.

Figure 2, continued.

next try for that target. Because this between-try time was dependent on individual subjects and even on different experimenters' behavior, a cleaner response time was also measured, called scan time. Scan time was defined as the cumulative time that the cursor was actually actively scanning in the case of the auto scan systems or the time that the cursor was actively controllable by the subject, in the case of the directed scan system. The data analysis was performed on the cleaner scan time measure. All responses (both erroneous and correct) were recorded. After 6 erroneous responses for any single trial, however, the computer terminated the trial automatically. We assumed that further attempts by the subject to select the correct response would only lead to fatigue and frustration.

Experimental Stimuli

Single letters were chosen for this task even though a communication device might be used to communicate whole words and sentences. In this study we were interested in learning whether the experimental system permitted faster and more accurate selection by the user, rather than obtaining a words per minute communication speed. A subsequent study could address communication speed for this interface. But there was little point in measuring communication speed unless it was first determined if the 2-switch, directed scan system could be operated by the target population with any more accuracy and speed than the row/column scanning system.

Research assistants worked closely with the subjects. They made sure they were physically comfortable and not intimidated by the experimental setting. They tried to encourage the subjects if necessary, without influencing their performance differentially on the four types of experimental systems. They operated the computer and input such identifying data as necessary, and had complete control over the experimental situation while it was running. Since knowledge on their part of the hypotheses of the study could have lead to their unconscious influence on the subject's behavior and performance scores, they were told only that we wished to evaluate the subject's performance on the four types of control and display configurations over time. This was intended to insure that each scanning system was treated equally in the testing.

## RESULTS AND DATA ANALYSIS

Analysis of variance (AOV) tests (Winer, 1962; Wollach, 1983) were used to determine which of the experimental variables produced statistically significant effects on the scan time and error data. The two variables of interest, in addition to subjects, were the four types of control and display system, and the nine experimental runs that were made by each subject with each of the four systems. The 0.05 level was selected as the cutoff point for statistical significance.

Two problems made the results of the experiment more difficult to analyze. First, due to procedural problems, some runs were not done with the system which had been chosen for that run. These are indicated by the dotted-line gaps in the curves for individual subjects (given in Appendix 1). Note that the data points before the gap are at about the same level as after, showing that the interpolated wrong runs did not affect the time data. Thus, the problem with order was ignored in all data analyses. The second problem was that not all subjects were able to use the same machine-paced scan rate throughout the experiment. Rather than postpone a run until the subject was able to operate the switch at a previously-run rate, runs were completed at a rate which the subject could use. Thus, subjects 2,3, and 6 used two different rates. Their times to successfully select the target letter are affected on those runs where they used the different rate. See Table 3 for the scan rates used for each subject and the actual order in which different systems were run.

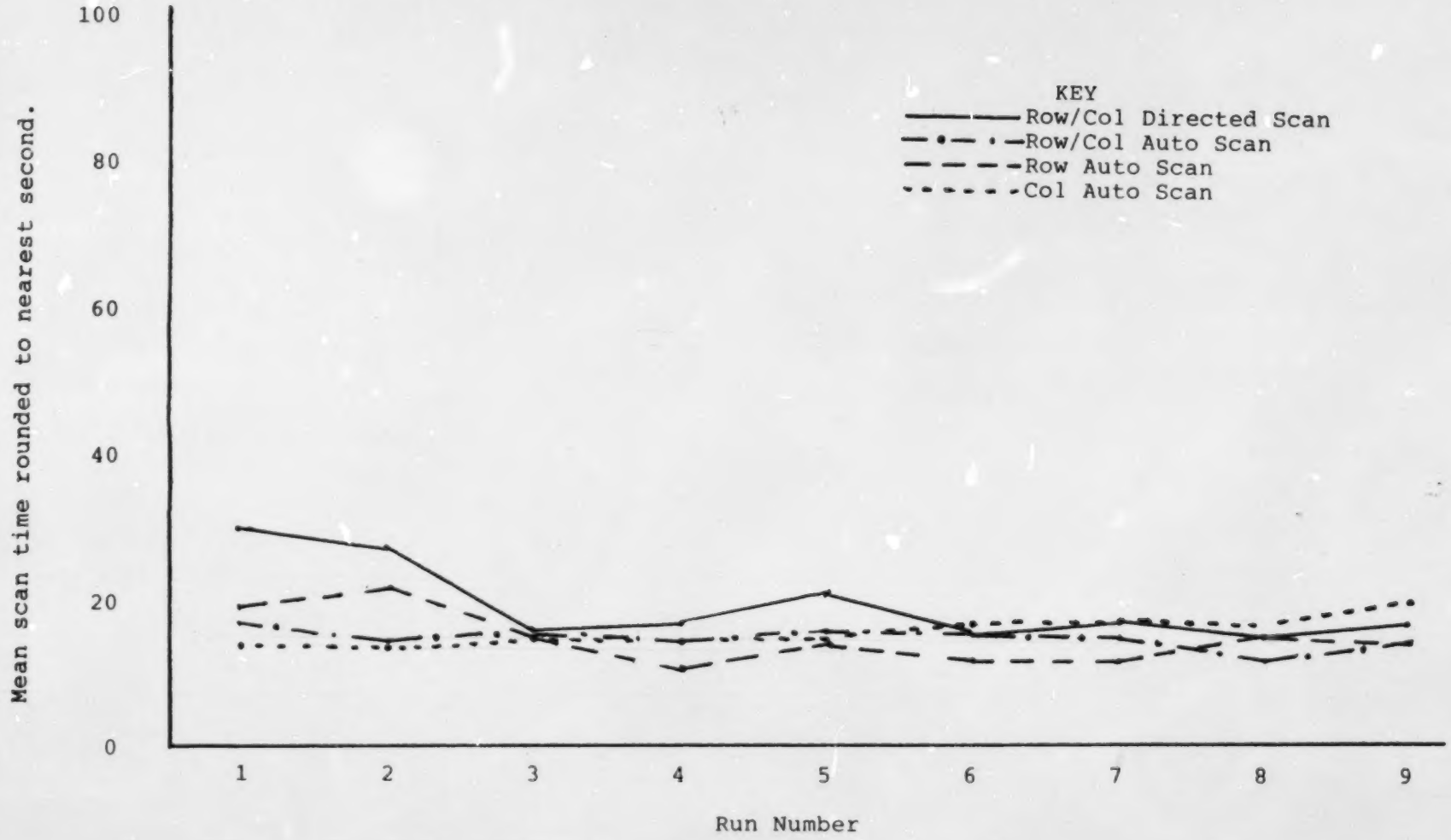
TABLE 3. SCAN RATES USED BY INDIVIDUAL SUBJECTS FOR NINE RUNS FOR EACH OF FOUR SYSTEMS, IN ORDER OF SYSTEMS USED

| SUBJECT | SYSTEM | | | |
|---|---|---|---|---|
| NUMBER | FIRST | SECOND | THIRD | FOURTH |
| 1 | C/1.0 | D/1.0 | B/1.0 | A/1.0 |
| 2 | D/2.0 | A/1.0 | B/2.0 | C/2.0 3 runs<br>C/1.0 6 runs |
| 3 | A/1.0 | B/1.0 | C/0.5 | C/0.5 |
| 4 | B/1.0 6 runs<br>C/1.0 3 runs | A/1.0 | B/1.0 3 runs<br>D/1.0 6 runs | D/1.0 6 runs<br>C/1.0 6 runs |
| 5 | D/1.0 | C/1.0 3 runs<br>B/1.0 6 runs | B/1.0 3 runs<br>C/1.0 6 runs | A/1.0 |
| 6 | C/1.0 | D/1.0 | A/1.0 | B/1.0 |

A=ROW/COLUMN DIRECTED B=ROW/COLUMN AUTO
C=ROW AUTO D=COLUMN AUTO

From the point of view of pure science, this is a problem with the data because it confounds the variables of scan time and system. However, from a practical point of view, one could argue that on that day, that particular person could not have operated at the faster rate (or would have made many more errors in so doing) so the longer times are realistic reflections of his capability with that particular system. And, we certainly did want to assess the variablility in scan time performance for individual subjects and our sample as a whole over time.

Figure 3. Mean scanning time to select correct target, for four systems, by run. N= 6 subjects.



Scan Time Data Analysis

Table 4 shows the overall means and standard deviations of scan time and adjusted scan time (see below for description of the adjustment) for each of the four systems.

TABLE 4. MEAN SCAN TIME AND MEAN ADJUSTED SCAN TIME IN SECONDS FOR FOUR SYSTEMS ACROSS 9 RUNS PER SYSTEM AND 6 SUBJECTS.

| | SCAN TIME | | ADJUSTED SCAN TIME | |
|---|---|---|---|---|
| | MEAN | SD | MEAN | SD |
| ROW/COL DIRECTED | 19.4 | 6.9 | 28.9 | 14.0 |
| ROW/COL AUTO | 15.1 | 6.5 | 30.6 | 19.2 |
| ROW AUTO | 15.0 | 5.0 | 25.3 | 14.8 |
| COLUMN AUTO | 15.8 | 8.1 | 24.5 | 12.7 |

AOV's were conducted with the variable rate subjects included, Table 5, and with them excluded, Table 6. Table 5 shows the results of a 2-Way AOV of the effects on scan time for systems by runs for all six subjects.

TABLE 5. ANALYSIS OF VARIANCE FOR SCAN TIMES

| SOURCE | SS | DF | MS | F | p |
|---|---|---|---|---|---|
| Subjects | 5947.7 | 5 | 1189.5 | 26.82 | <0.0001 |
| System | 693.2 | 3 | 231.1 | 1.72 | 0.2 |
| Subj. x Sys | 2005.0 | 15 | 133.7 | | |
| Runs | 783.2 | 8 | 97.9 | 2.06 | 0.063 |
| Runs x Ss | 1902.9 | 40 | 47.6 | | |
| Sys x Runs | 1356.6 | 24 | 56.5 | 1.76 | 0.024 |
| Sys x R x Ss | 3852.6 | 120 | 32.1 | | |
| Total | 16541.3 | 215 | | | |

There was no significant effect for system (p=0.2), but runs approached significance (p=0.063). The interaction between systems and runs was significant (p=0.024) however, as was subjects (p<.0001). Table 6 shows the same analysis done for only the three subjects who used a consistent scan rate across all systems and runs.

TABLE 6. ANALYSIS OF VARIANCE FOR THREE SUBJECTS' SCAN TIMES

| SOURCE | SS | DF | MS | F | p |
|---|---|---|---|---|---|
| Subjects | 2475.5 | 2 | 1237.5 | 37.68 | <0.0001 |
| System | 399.2 | 3 | 133.1 | 1.27 | ns |
| Ss x Sys | 629.6 | 6 | 104.9 | | |
| Runs | 104.6 | 8 | 13.1 | .26 | ns |
| Runs x Ss | 802.9 | 16 | 50.2 | | |
| Runs x Sys | 421.6 | 24 | 17.6 | .97 | ns |
| R x Sys x Ss | 866.8 | 48 | 18.0 | | |
| Total | 5700.2 | 107 | | | |

As expected, reducing the number of subjects in the analysis to just three lowers the F ratios, but the strongest effect (subjects) is still significant; the significant runs by systems interaction, significant with 6 subjects, reduces to insignificance. The nearly significant (p=0.063) effect of runs in the 6-subject analysis also disappears with the reduced number of subjects. Figure 2, which shows mean scan times for the four systems across the nine runs graphically demonstrates the AOV results. As can be seen no one system is consistently better or worse than the others.

Extensive massaging of the data did not seem called for, although log transforms or normalizing the scan time data might tease a significant systems effect out of the scan time data to match the error data. However, one transformation did seem to be worthwhile. On those trials where errors were made, an actual communication device would require that the user correct the error in some fashion. If it takes as long to correct an error as to make a correct selection (which would be typical), then that time should be included in the measure of effectiveness of the system.

The scan times were adjusted by the number of errors made on that trial, by the following formula:

$$MASST = \frac{SST\ (12 + \sum_{i=1}^{12} M_i)}{H}$$

Where:

H = number of hits
SST = selection scanning time
M = number of misses
MASST = mean adjusted selection scanning time

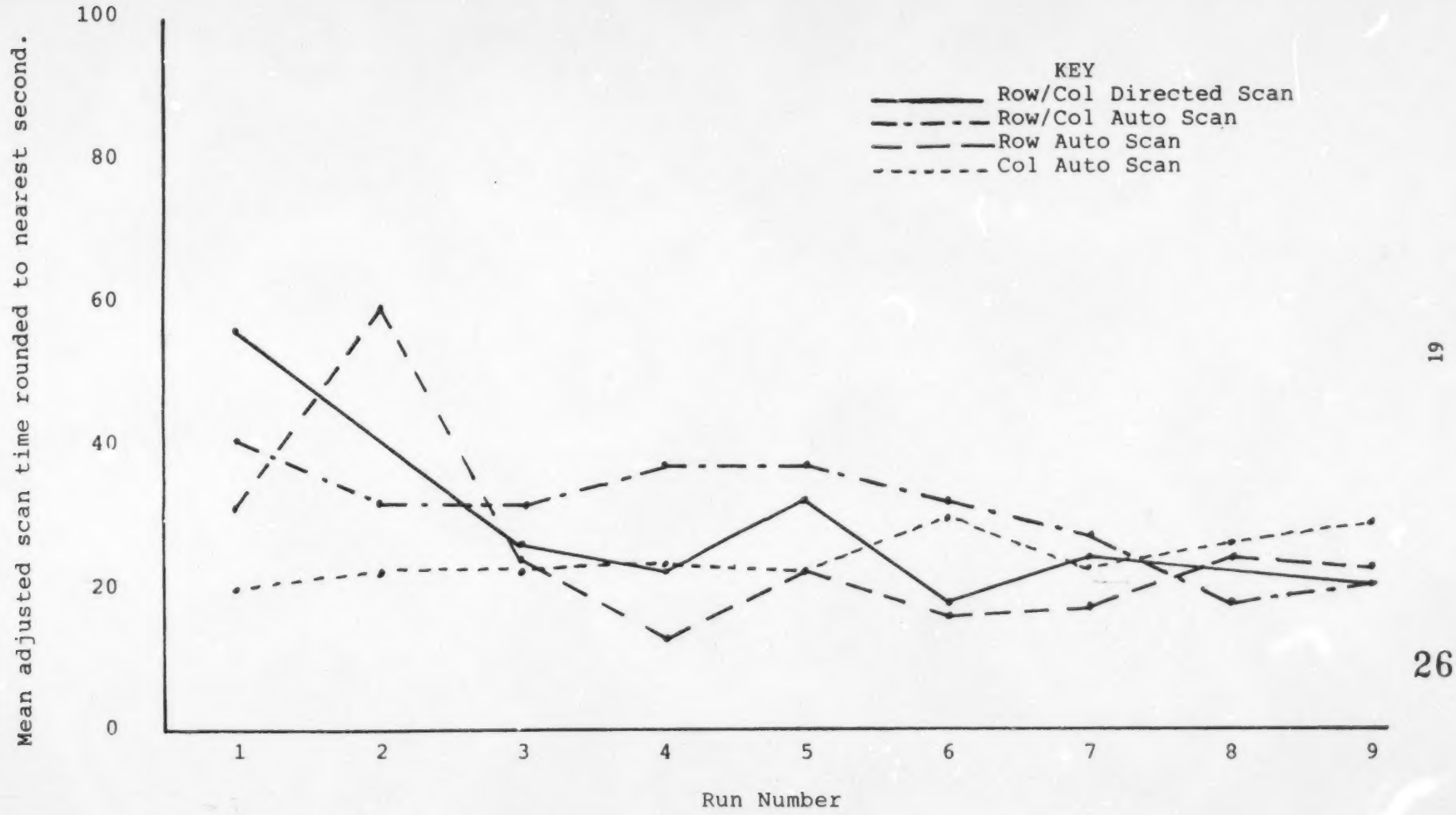
The data were analyzed as before, with the results shown in Table 7.

TABLE 7. ANALYSIS OF VARIANCE FOR ADJUSTED SCAN TIME DATA

| SOURCE | SS | DF | MS | F | p |
|---|---|---|---|---|---|
| Subjects | 32680.8 | 5 | 6536.2 | 15.6 | <0.0001 |
| Systems | 1378.1 | 3 | 459.4 | .69 | ns |
| Ss x Sys | 9935.0 | 15 | 662.3 | | |
| Runs | 6975.1 | 8 | 872.0 | 1.95 | 0.079 |
| Runs x Ss | 17889.3 | 40 | 447.2 | | |
| Runs x Sys | 12521.9 | 24 | 521.7 | 1.38 | 0.132 |
| R x Sys x Ss | 45426.0 | 120 | 378.6 | | |
| Total | 126806.2 | 215 | | | |

As before, subjects is significant, runs approaches significance (p=0.079), and the runs by system interaction shows a trend (p=0.132). Figure 3 again graphically illustrates the lack of any consistent advantage of one system over another in scan time.

Figure 4. Mean scanning time to select correct target, adjusted for error correction time, for four systems, by run. N= 6 subjects.



Error Data and Analysis

Table 8 shows the total number of misses made by all subjects for each of the four systems.

TABLE 8. TOTAL NUMBER OF MISSES MADE BY SIX SUBJECTS FOR EACH OF FOUR SYSTEMS.

| | SYSTEM | | | |
|---|---|---|---|---|
| | ROW/COL DIRECT | ROW/COL AUTO | ROW AUTO | COLUMN AUTO |
| TOTAL MISSES | 249 | 451 | 289 | 281 |

The error analysis, Table 9, is a simple 1-way AOV with system as the variable under test, and a significant ($p=0.0005$) effect due to system is shown.

TABLE 9. ANALYSIS OF VARIANCE TABLE FOR ERROR DATA

| SOURCE | SS | DF | MS | F | p |
|---|---|---|---|---|---|
| System | 49.3 | 3 | 16.4 | 6.18 | <0.001 |
| Subjects | 319.9 | 5 | 64.0 | 24.10 | <0.001 |
| Sys x Ss | 107.5 | 15 | 7.2 | 2.70 | <0.005 |
| Within | 504.9 | 190 | 2.6 | | |
| Total | 981.6 | 213 | | | |

Duncan's Multiple Range Test (Bruning & Kintz, 1968) shows that the only system significantly different from any of the others is row-column auto scan, significantly worse than any of the others. The data are not stable enough to support more detailed analysis, however, as Table 10 shows; this AOV attempts to analyze effects due to subjects, runs, and systems. The data analyzed in Table 10 are conservative in that they understate the number of misses that would probably have been made in a real world communication situation because subjects never accumulated more than 6 misses for a given trial or attempt at selecting a particular target letter. This was done to reduce frustration for those cases when a subject after repeated tries was unable to select the target letter. Thus, for the data analyzed in Table 10, six recorded misses for a target that was never successfully selected could in the real world have been more than six misses until the target was selected, if it ever was.

TABLE 10. ANALYSIS OF VARIANCE FOR ERROR, BY RUNS.

| SOURCE | SS | DF | MS | F | p |
|---|---|---|---|---|---|
| Subjects | 2878.0 | 5 | 575.6 | 22.26 | <0.001 |
| Systems | 443.9 | 3 | 248.0 | 2.30 | 0.14 |
| Ss x Sys | 966.5 | 15 | 64.4 | | |
| Runs | 351.4 | 8 | 43.9 | 1.93 | 0.82 |
| Ss x Runs | 911.6 | 40 | 22.8 | | |
| Sys x Runs | 588.0 | 24 | 24.5 | 1.11 | ns |
| Ss x Sys x Runs | 2646.7 | 120 | 22.1 | | |
| Total | 8786.1 | 215 | | | |

The results of the AOV show that the effect of runs approaches significance (p=.082, Table 10) and systems shows a trend (p=.14). As before, subjects is a significant effect.

Table 11 shows the total number of successful target selections and failures in target selection for each system. For a given target, the selection was scored as a success as long as the subject managed to select the target correctly within six tries. If he or she missed six times on the same target, then that trial was scored as a failure and a new target was presented.

TABLE 11. NUMBER OF FAILURES AND OF SUCCESSFUL TARGET SELECTIONS FOR EACH OF FOUR SYSTEMS. N=6 SUBJECTS, EACH PERFORMING 108 TARGET TRIALS PER SYSTEM.

| | ROW/COL DIRECT | ROW/COL AUTO | ROW AUTO | COLUMN AUTO |
|---|---|---|---|---|
| FAILURES | 2 | 13 | 2 | 7 |
| SUCCESSES | 646 | 635 | 646 | 629* |

A Chi-Square analysis (Bruning and Kintz, 1968) showed a significant effect for system ($x^2$ = 13.77, df = 3, p = .0032)as can be seen from the table above, the Row/Column Auto Scan system's failure rate was nearly double that of the next worse system—Column Auto Scan—and was over six times the rate of either the Row/Column Direct or the Row Auto Scan system.

Appendix 1 contains figures showing individual subjects' mean scan times and mean adjusted scan time by runs for each system, and tables listing number of misses and number of failures to select the target, by run, for each system.

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*Procedural problems due to fatigue of one subject reduced the total number of trials for the Column Auto Scan System to 636 instead of the 648 trials achieved for the other three systems

## DISCUSSION

Other control techniques using single switches and variations of the techniques used in this study have recently been reported. Two are discussed here.

A new technique, "critically damped scanning", might increase the usefulness of linear scanning using a single switch. (Vanderheiden, 1981). The scanning rate is initially 4 to 5 times the rate at which the user can reliably respond. It is assumed that when the user activates the switch to make a selection, the indicator will have moved several items beyond the user's intended selection before the user can halt the scan. When the user activates the switch again, the indicator will begin to scan in the reverse direction at a much slower rate. The user must activate the switch when the indicator returns to the desired selection.

Critically damped scanning may also prove useful to individuals with uncontrollable movements. As found in this study, the subjects were more accurate using linear scanning than they were using row/column scanning. Critically damped scanning might enable this population to access a larger number of items using the more reliable linear scanning system. However, our data suggest that this population will still have difficulty with a relatively high error rate, due to under and overshoots when the cursor is moving backward toward their intended selection.

In a pamphlet, Zygo Industries, Inc. (1983) have listed some guidelines for the use of row/column scanning devices. These include:

1) The entire matrix must always be in view of the user;

2) The entire row should be indicated or illuminated during the row scanning phase;

3) A time interval is needed for confirmation or correction after an item is selected (i.e. the item selection can be negated if the operating control is activated during this period; and

4) The user should be trained to fixate on the desired selection, not on the lights as they scan, waiting for the desired selection to be indicated or illuminated.

Zygo Industries Inc., (1983) reports that users with severe athetoid cerebral palsy showed possible scanning speeds faster than 0.25 sec/step. Although scan speeds are high, so was false selection/correction activity. Most users had difficulty making desired choices in the first rows or columns after the switch was activated. It was found that when the scan rate is decreased

after a switch activation and gradually increased to the fast rate, the accuracy improved as well as the average scan rate.

In our study, the errors were evenly distributed throughout the row- column scanning display. We did not see any more errors made in the first row or first column than any of the other rows and columns. The scanning strategies suggested by Zygo would be particularly effective if they do decrease the errors made in the first rows and columns, if the display is designed to take advantage of this by having the most frequently used items placed in these positions.

## CONCLUSIONS

It will come as no surprise to anyone that the performance of the individual subjects was a significant effect. Even subjects as rigorously selected as these varied immensely in their ability to use a single selection switch, and indeed varied in that ability from day to day, and in some cases from hour to hour. What this study has re-emphasized about this, however, is that good scientific research can be done on these people, and that one does not always have to resort to "clinical judgment" when dealing with a diverse population like this.

We tried to do enough practice runs with the system so that learning or practice was not a factor, and in this we seem to have succeeded fairly well. Inspection of the graphs in Appendix A will show a slight improvement from run 1 to run 9 no matter what the system was. Most of this gain occurred in the first three runs. The statistical analyses found the "runs" factor to be only marginally significant. In addition, the counterbalancing which was done in the design prevented learning from affecting any one system differentially; so we can conclude that learning or practice was probably not a factor in the differences between systems.

An important implication of this is that the two hours practice was sufficient time for these subjects to have reached at least a learning plateau, if not an asymptote, in the use of these systems. While these were fairly simple control/display systems the subjects did have to adapt to new switches, a new situation, people they had not met before, a novel task, and a computer which they had not worked with before. It is useful to know that two hours practice is sufficient to almost completely eliminate the effects of learning/practice with this subject population. This finding alone could save many hours of unnecessary "training" which children like these are subjected to when they are introduced to a new communication system.

Examination of the overall mean times shows that the row-column auto-significantly so, of the systems tested, and even with the small number of subjects tested is statistically significantly worse in terms of number of errors made. The errors certainly lead to frustration and user dissatisfaction. If time to correct these errors is allowed for in scanning time calculations, then the row-column auto-scanning is also worst, though not significantly so, in terms of time to correctly select a letter.

It should be noted here that these subjects were persons who would normally be prescriptively limited to a single-switch input device, since their motor control is so poor. It is a very important finding of this study that such people can in fact run a two-switch directed-scan system, and experience less frustration due to fewer errors, and in addition can equal or better the output speed of the three auto scan types of systems which are traditionally prescribed for them.

It seems that there is something about the arrangement of items to be selected into rows and columns which makes it more difficult for these people to deal with them. The number of items which can be put in a single row or column is limited by the practical considerations of display size and the length of time taken to scan from one end of the display to the other. This makes single row or single column displays limited in the number of items which can efficiently be placed in them. A simple analysis of scan rate and the number of items that must, on the average be passed over in order to reach the target, would seem to dictate putting items into rows and columns in order to minimize scan time. Information theory supports the traditional approach, telling us that square matrices are more efficient than those having unequal numbers of rows versus columns. For users who can use a scanning system with high accuracy this might be so, but it is certainly not the case for the subjects included in this study. We are fairly confident in recommending that people who meet the selection criteria outlined earlier in this report should not be given a row-column autoscan system as a communication aid. Our data show that instead, a row autoscan system would work well for them if enough could be fit onto a single row to meet their needs; if not, they should be trained to use two switches and fitted with a row-column directed scan system. We would predict that their error rate would be lowest with the row-column directed scan, and their speed would be close to that achieved with the single row. A major contribution of this project is, in fact, the ease with which persons in this group can be identified. Anyone with a Radio Shack Model I or Model III computer can perform this diagnostic test merely by requesting a copy of the program from Children's Hospital and having the potential user run the subject selection program. A copy of the program listing, in Radio Shack Basic, is given in Appendix II of this report.

Another major finding of this study is that individuals who would have been or had already been prescribed a single switch system were in fact able to operate two switches. We emphasize that we did not look for persons who could perhaps operate two switches; rather, the subjects who were selected by our screening program later demonstrated an ability to use two switches. This represents a doubling of channel capacity in the information theory sense. Certainly all attempts should be made for this group of users to find a second switch that they can reliably operate when not under the rigid time pressure of an automatic scanning system.

## IMPACT

The results of this research will benefit a large group of physically disabled individuals who are now unable to effectively use commercially available communication aids and other assistive devices that use the row/column scanning system. At the very least, we have learned more about the capabilities of this group. At best, we will find that by applying the findings of this study, we can improve their control of devices in the three areas of speed, accuracy, and adequacy (Barker and Cook, 1980) if these devices are only slightly modified. A by-product of the project is the software. Since the software is designed for a microcomputer that is in widespread use in schools, it can be made available to schools to provide access to computer assisted instruction and assessment to a group of children who are presently unable to control computers. Since control and display systems apply to the entire gamut of assistive devices, the impact of these very specific findings will be greatly multipied.

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## APPENDIX 1

TABLE 12. NUMBER OF MISSES/FAILURES BY RUN FOR EACH OF FOUR SYSTEMS FOR SIX SUBJECTS

| | | SYSTEM | | | |
|---|---|---|---|---|---|
| | | ROW/COL DIRECT | ROW/COL AUTO | ROW AUTO | COL AUTO |
| SUBJECT | RUN | | | | |
| 1 | 1 | 1/0 | 9/1 | 20/0 | 8/0 |
| | 2 | 0/0 | 18/0 | 43/4 | 3/0 |
| | 3 | 2/0 | 15/0 | ---- | 3/0 |
| | 4 | 2/0 | 33/1 | 5/0 | 20/1 |
| | 5 | 6/0 | 20/0 | 10/0 | 16/0 |
| | 6 | 1/0 | 18/1 | 4/0 | 30/3 |
| | 7 | 3/0 | 9/0 | 8/0 | 7/0 |
| | 8 | 3/0 | 8/0 | 8/0 | 3/0 |
| | 9 | 0/0 | 4/0 | 11/0 | 3/0 |
| 2 | 1 | 12/0 | 16/1 | 1/0 | 2/0 |
| | 2 | 6/0 | 15/0 | 0/0 | 5/0 |
| | 3 | 10/0 | 10/0 | 1/0 | --- |
| | 4 | 3/0 | 6/0 | 2/0 | 1/0 |
| | 5 | 13/0 | 7/0 | 4/0 | 3/0 |
| | 6 | 2/0 | 6/0 | 5/0 | 3/0 |
| | 7 | 2/0 | 10/0 | 2/0 | 3/0 |
| | 8 | 1/0 | 2/0 | 9/0 | 7/0 |
| | 9 | 4/0 | 8/0 | 4/0 | 6/0 |
| 3 | 1 | 10/0 | 11/0 | 5/0 | 4/0 |
| | 2 | 5/0 | 3/0 | 0/0 | 1/0 |
| | 3 | 3/0 | 3/0 | 2/0 | 2/0 |
| | 4 | 5/0 | 3/0 | 1/0 | 0/0 |
| | 5 | 5/0 | 1/0 | 0/0 | 0/0 |
| | 6 | 3/0 | 0/0 | 1/0 | 1/0 |
| | 7 | 2/0 | 5/0 | 1/0 | 0/0 |
| | 8 | 0/0 | 0/0 | 4/0 | 0/0 |
| | 9 | 2/0 | 0/0 | 1/0 | 1/0 |
| 4 | 1 | 1/0 | 6/0 | 1/0 | 0/0 |
| | 2 | 2/0 | 1/0 | 3/0 | 0/0 |
| | 3 | 0/0 | 7/0 | 2/0 | 0/0 |
| | 4 | 5/0 | 0/0 | 0/0 | 1/0 |
| | 5 | 3/0 | 1/0 | 0/0 | 0/0 |
| | 6 | 4/0 | 0/0 | 0/0 | 1/0 |
| | 7 | 2/0 | 1/0 | 0/0 | 0/0 |
| | 8 | 1/0 | 2/0 | 0/0 | 0/0 |
| | 9 | 6/0 | 2/0 | 1/0 | 0/0 |

TABLE 12. CONTINUED

| SUBJECT | RUN | SYSTEM ROW/COL DIRECT | ROW/COL AUTO | ROW AUTO | COL AUTO |
|---|---|---|---|---|---|
| 5 | 1 | 18/0 | 16/0 | 3/0 | 3/0 |
| | 2 | 3/0 | 11/1 | 3/0 | 2/0 |
| | 3 | 0/0 | 5/0 | 6/0 | 7/0 |
| | 4 | 4/0 | 1/0 | 0/0 | 1/0 |
| | 5 | 2/0 | 6/0 | 0/0 | 0/0 |
| | 6 | 4/0 | 9/0 | 1/0 | 1/0 |
| | 7 | 4/0 | 12/1 | 6/0 | 4/0 |
| | 8 | 0/0 | 12/0 | 3/0 | 5/0 |
| | 9 | 1/0 | 9/0 | 9/0 | 8/0 |
| 6 | 1 | 13/1 | 25/2 | 14/1 | 10/0 |
| | 2 | 11/0 | 12/0 | 19/0 | 17/1 |
| | 3 | 13/0 | 16/2 | 12/0 | 13/1 |
| | 4 | 7/0 | 5/0 | 1/0 | 11/0 |
| | 5 | 8/0 | 19/2 | 14/1 | 9/0 |
| | 6 | 1/0 | 17/1 | 10/0 | 9/0 |
| | 7 | 9/0 | 8/0 | 8/0 | 14/0 |
| | 8 | 14/1 | 2/0 | 10/0 | 22/1 |
| | 9 | 7/0 | 6/0 | 11/0 | 11/0 |

The number on the left of the slash is the number of misses for that run and the number on the right is the number of failures, i.e. the number of times there were six misses for the same target. Hyphens (---) indicate the two runs for which data was not collected due to subject fatigue.

SCAN RATES USED FOR SIX SUBJECTS

| | | | | |
|---|---|---|---|---|
| S1 | Row/Auto 1.0 | Col/Auto 1.0 | Row/Col Auto 1.0 | Row/Col Direct 1.0 |
| S2 | Col/Auto 2.0 | Row/Col Direct 1.0 | Row/Col Auto 2.0 | Row/Auto 2.0, 1.0 |
| S3 | Row/Col Direct 1.0 | Row/Col Auto 1.0 | Row/Auto 0.5 | Col/Auto 0.5 |
| S4 | Row/Col Auto 1.0 then Row/Auto 1.0 | Row/Col Direct 1.0 | Row/Col Auto 1.0 then Col/Auto 1.0 | Col/Auto 1.0 then Row/Auto 1.0 |
| S5 | Col/Auto 1.0 | Row/Auto 1.0 | Row/Col Auto 1.0 | Row/Col Direct 1.0 |
| S6 | Row/Auto 1.0 | Col/Auto 1.0 | Row/Col Direct 1.0 | Row/Col Auto 2.0 |

Figure 5a. Mean scanning time to select correct target using the Row/Column Directed Scan system, by run for 6 subjects.

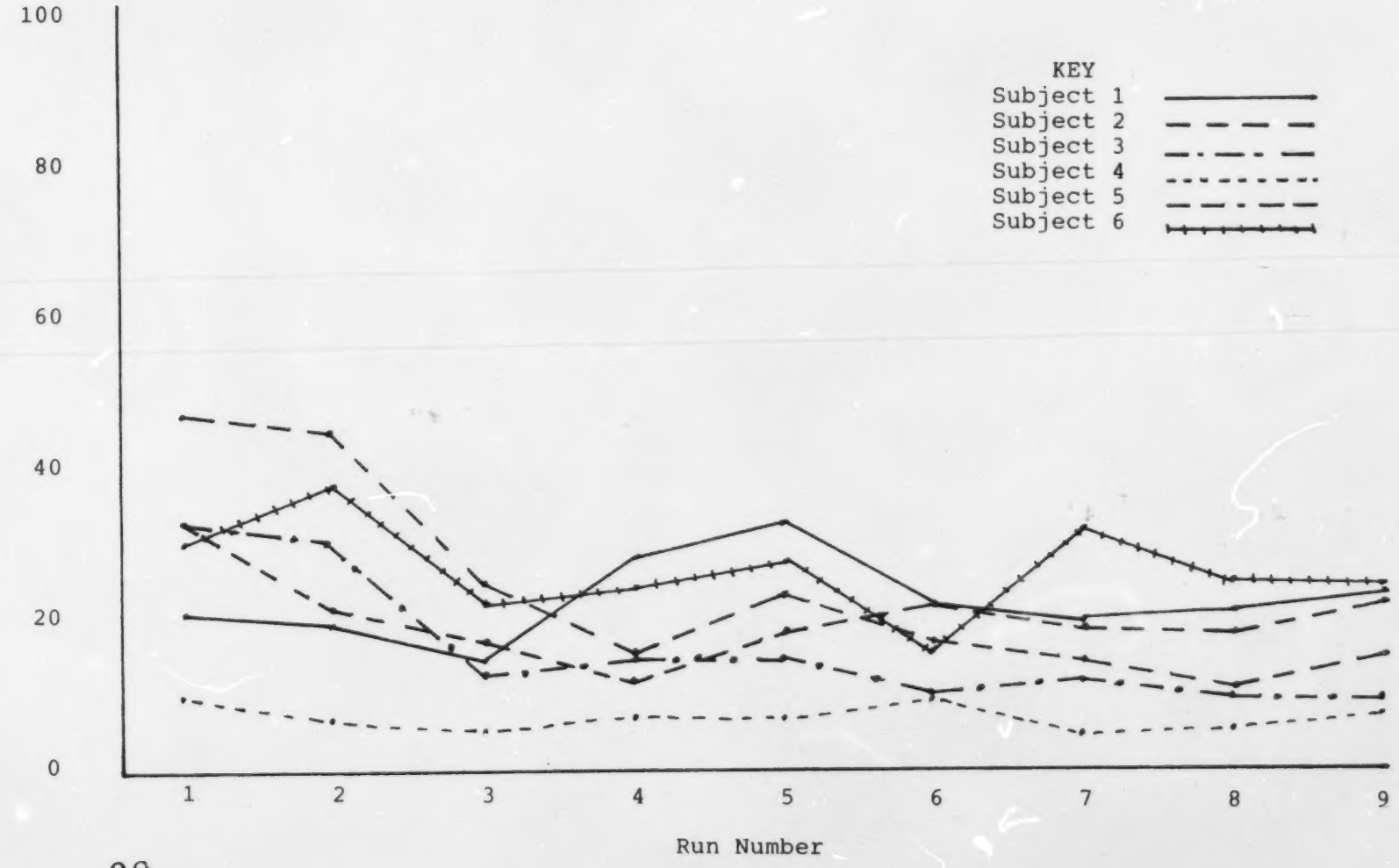


Figure 5b. Mean scanning time to select correct target using the Row/Column Auto Scan system, by run for 6 subjects.

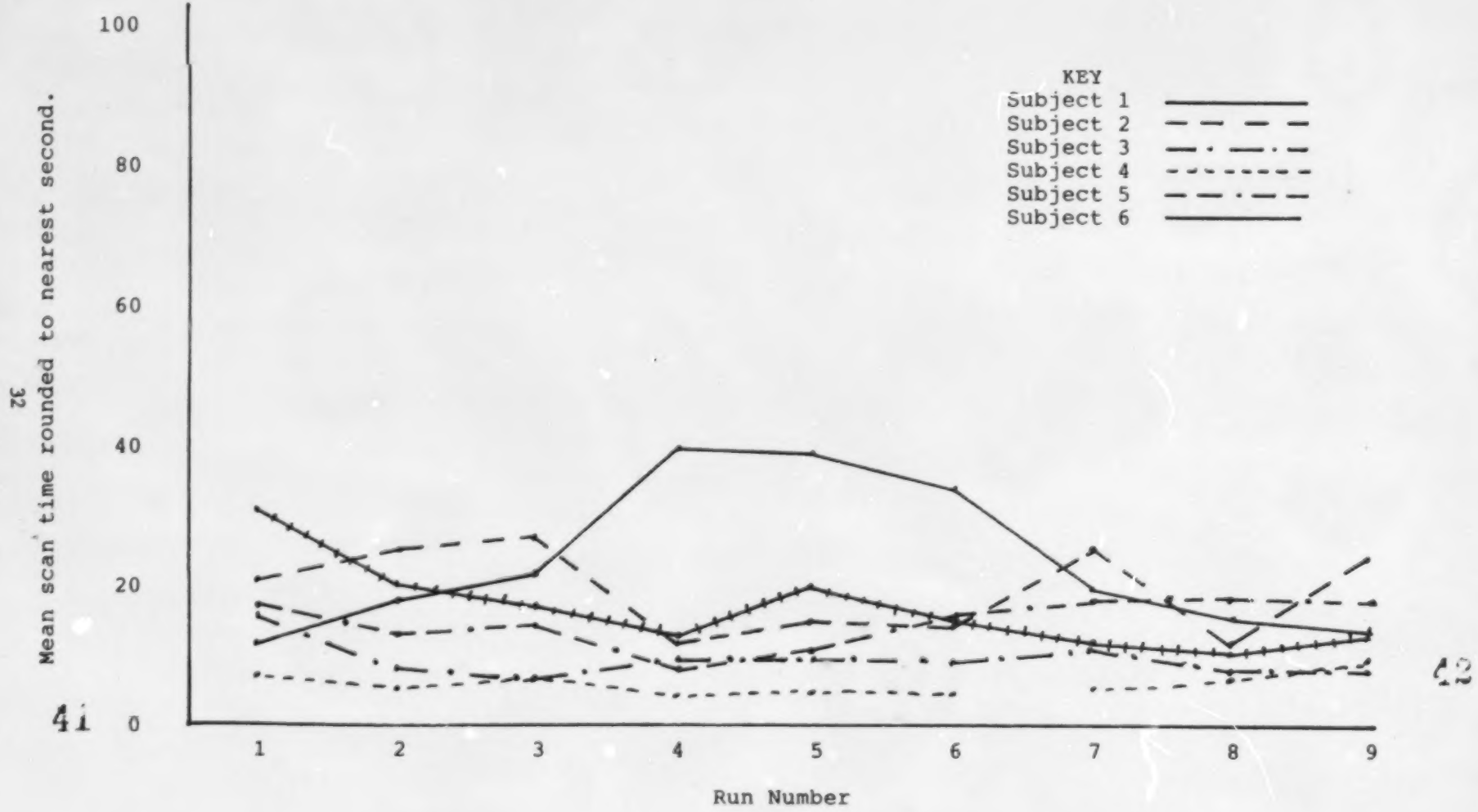


Figure 5c. Mean scanning time to select correct target using the Row Auto Scan system, by run for 6 subjects.

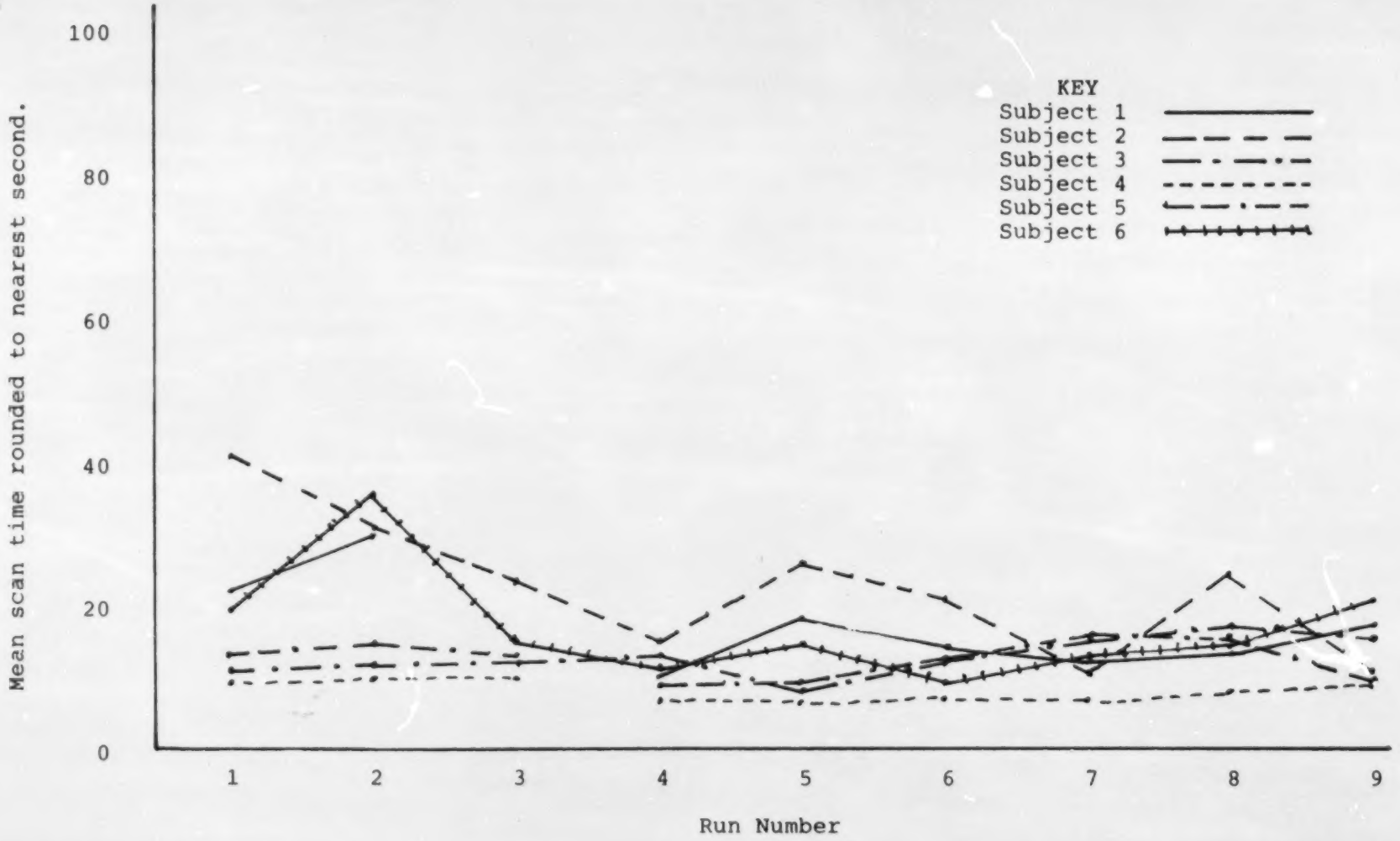


Figure 5d. Mean scanning time to select correct target using the Column Auto Scan system, by run for 6 subjects.

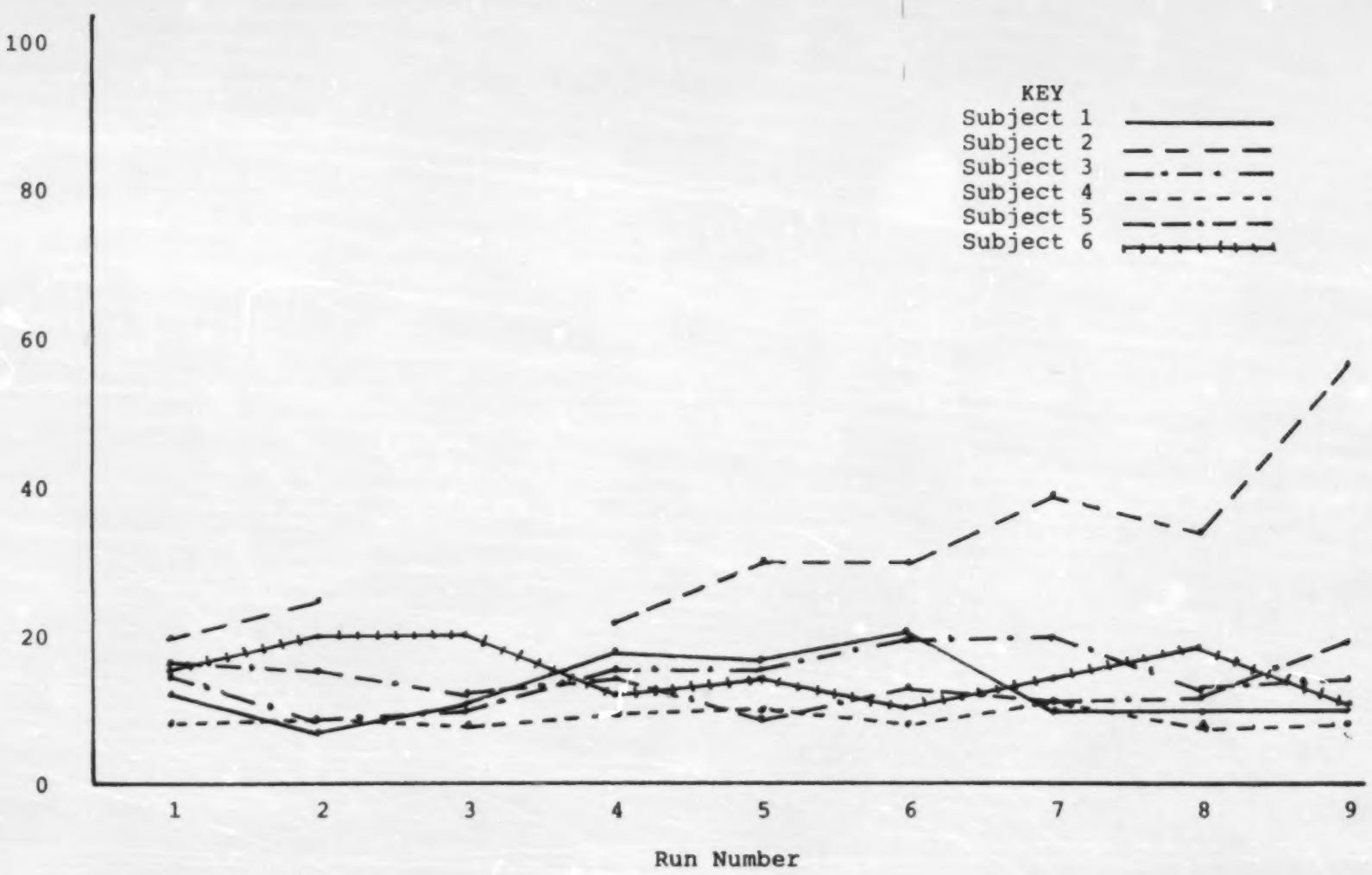


Figure 6a. Mean scanning time to select correct target, adjusted for error correction time, using the Row/Column Directed Scan system, by run for 6 subjects.

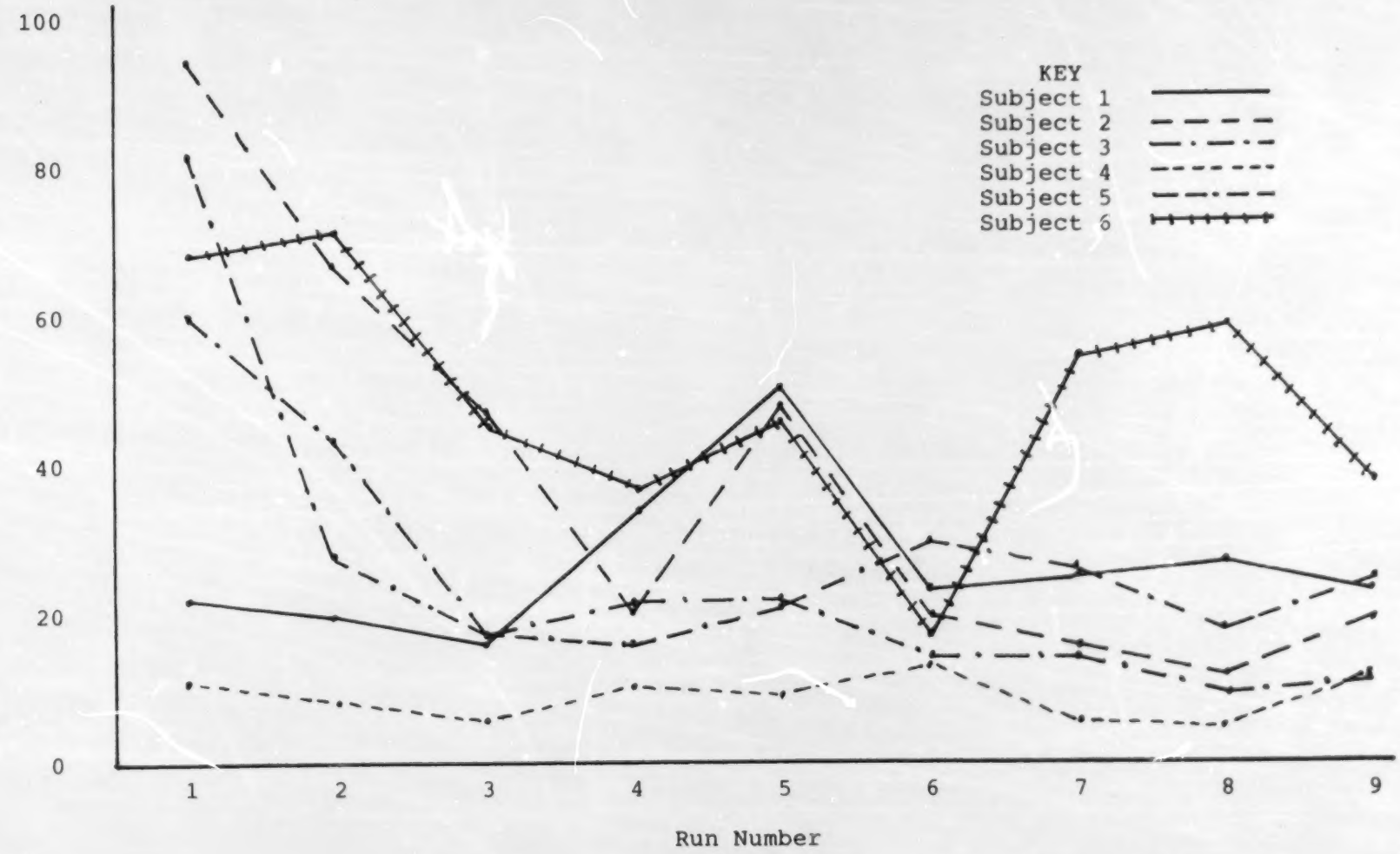


Figure 6b. Mean scanning time to select correct target, adjusted for error correction time, using the Row/Column Auto Scan system, by run for 6 subjects.

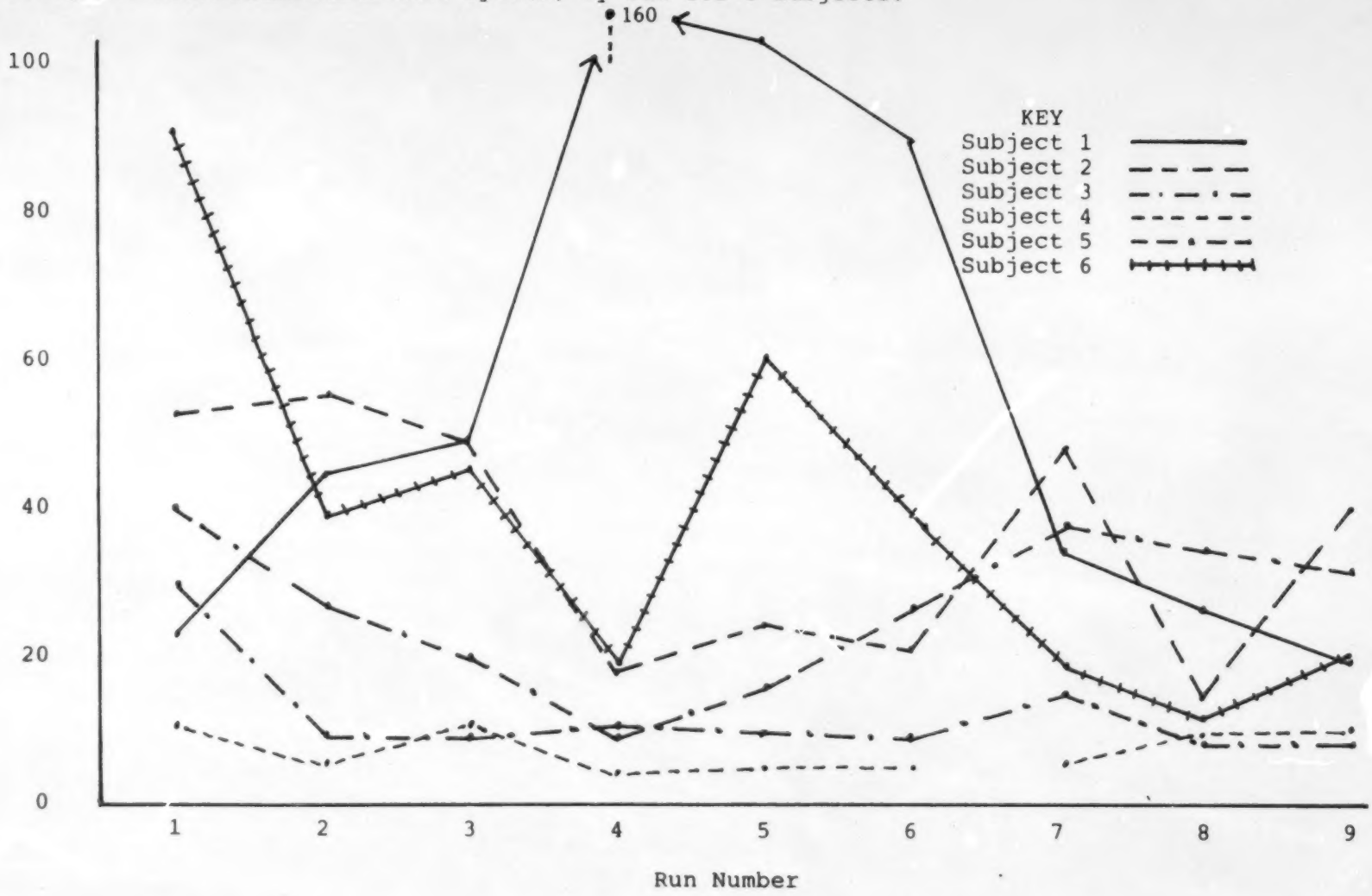


Figure 6c. Mean scanning time to select correct target, adjusted for error correction time, using the Row Auto Scan system, by run for 6 subjects.

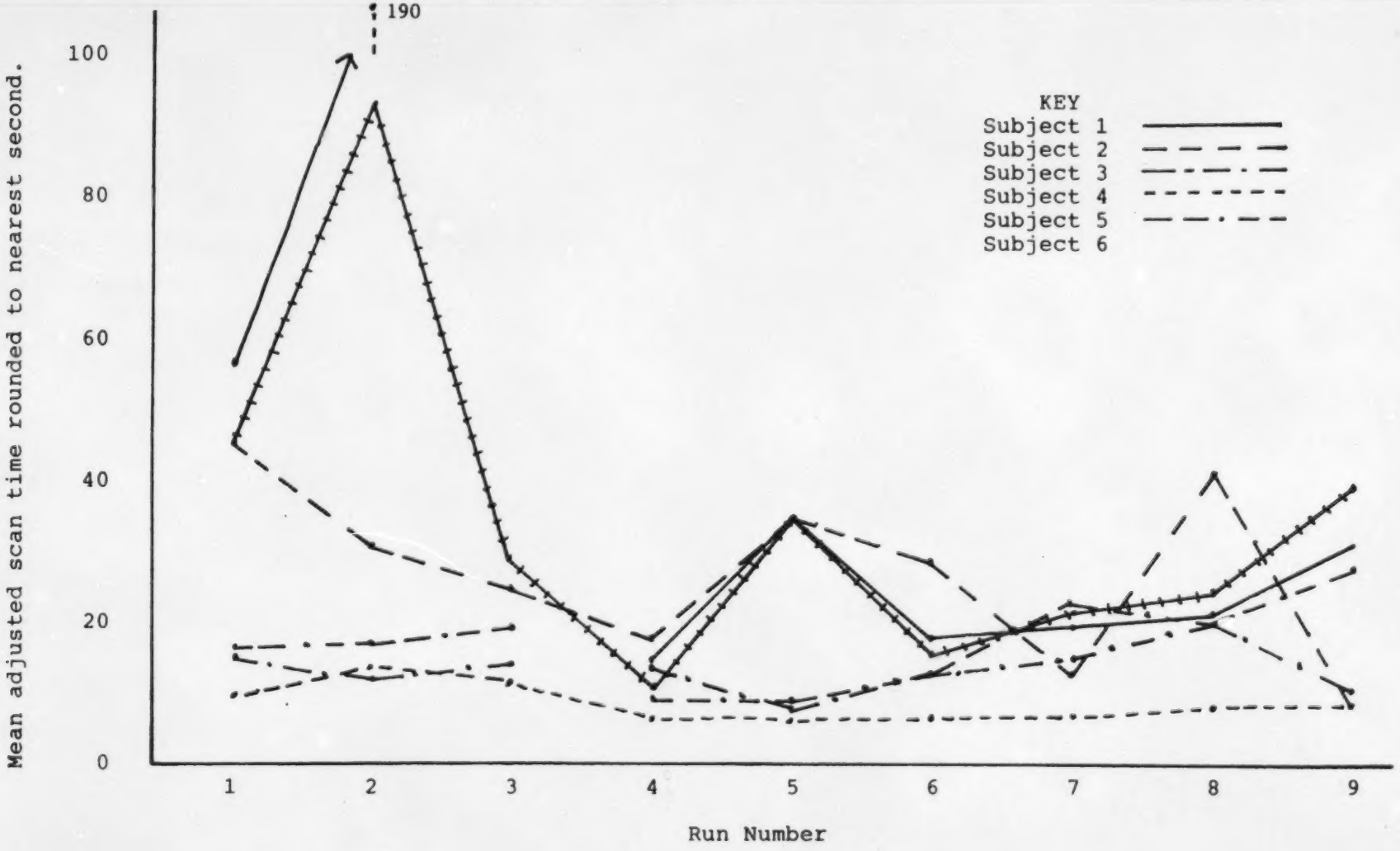
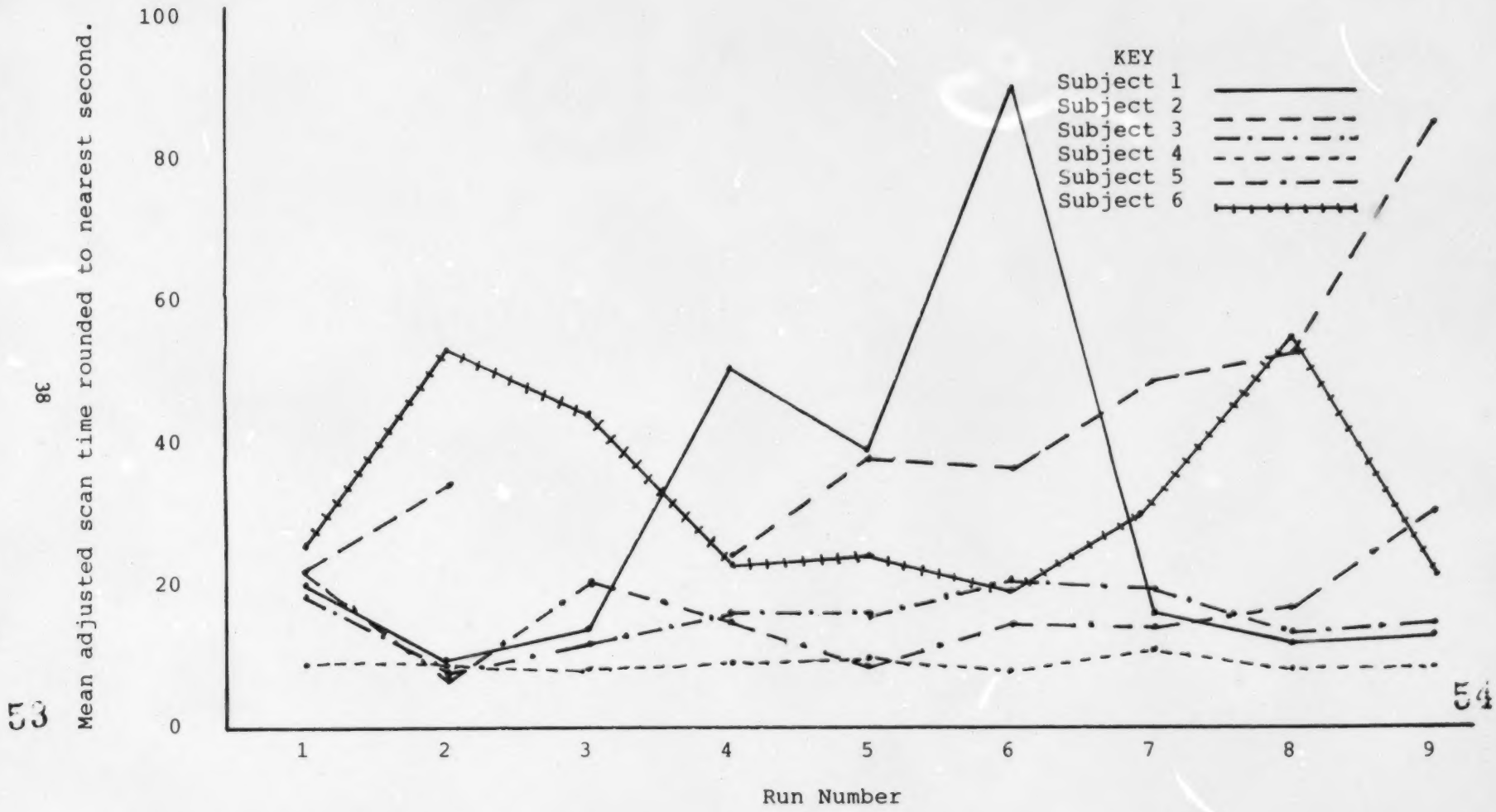


Figure 6d. Mean scanning time to select correct target, adjusted for error correction time, using the Column Auto Scan system, by run for 6 subjects.



## Appendix II

These two Basic programs for the TRS 80 Model 1 and 3 are used to screen for the problems regarding accuracy that can be encountered when using a single switch. SCREEN/BAS is used with a single switch that parallels the space bar. PRDATA/BAS is used to display the data collected when using SCREEN/BAS.

```
500 CLEAR 1000: GOSUB 9000: REM INITIALIZE POINTERS AND ARRAYS
510 GOSUB 8800: REM GET FILESPEC FOR DATA, VERIFY OK
520 SUBJFIN=0: REM 0=MORE SUBJECTS, -1=NO MORE
530 IF SUBJFIN THEN GOTO 899
540 REM BEGIN LOOP "RUN"
550   GOSUB 8700: REM GET SUBJECT ID AND RESET COUNTERS
560   GOSUB 6000: REM INIT ENTRY ARRAY
565   GOSUB 4900: REM RESET TARGET POOL
570   SBJCHANGE=0: REM 0=OLD SUBJECT, 1=NEW
580   IF SBJCHANGE THEN GOTO 859
590   REM BEGIN LOOP "TRIAL"
592     GOSUB 5600: REM CLS AND DISPLAY ENTRY ARRAY
595     TRIAL=TRIAL+1: GOSUB 6200: REM DISPLAY INFO
600     GOSUB 8600: REM SELECT TARG LETTER, COMPUTE TARG POSN
610     PASSES=0: REM FOR SCORING
620     VLID=-1: REM TRIAL VALID
630     GOSUB 8500: REM GET SCAN RATE
640     GOSUB 8400: REM DISPLAY TARGET, HOME CURSOR
649     REM DRIVE CURSOR AND WAIT FOR INPUT
650     K$="":GOSUB 8000
660     IF NOT(K$="ABORT") THEN GOTO 700: REM IF "ABORT" DO:
670       SKAWR=999: GOSUB 5000: REM CLEAR SCREEN
680       PRINT@5*64+20,"TRIAL ABORTED.":PRINT:PRINT:PRINT
690       GOTO 750: REM END OF "ABORT" DO BLOCK
700     REM BEGIN ELSE ("CHAR SELECTED") BLOCK:
710       GOSUB 3600: REM DISPLAY SELECTION
720       GOSUB 7800: REM COMPUTE SCORE
730       GOSUB 7600: REM DISPLAY SCORE? IGNORE OR COUNT TRIAL?
740     GOTO 750: REM END OF "CHAR SELECTED" BLOCK
750     IF NOT (SKAWR=999 OR IGNAWR) THEN GOTO 810
760     REM BEGIN ("ABORT" OR IGNORE) BLOCK:
770       VLID=0: REM INVALIDATE TRIAL
780       REM TARGET LETTER BACK TO POOL:
790       TAKEN(XY)=0: CHOICE=CHOICE+1
800       GOSUB 7500: REM ABORT SUBJECT?
810     REM END OF ("ABORT" OR IGNORE) BLOCK
820     GOSUB 7400: REM TEMPORARILY STORE DATA (THIS TRIAL)
830     IF VLID THEN GOSUB 7100: REM SUBJECT COMPLETE?
840     IF TRIAL=NMAX THEN GOSUB 4500: REM NOTIFY AND NEW SUBJ
858     GOTO 580: REM LOOP BACK TO "TRIAL"
859   REM END OF LOOP "TRIAL"
860   GOSUB 5700: REM DISPLAY SUBJECTS DATA SCREEN/PRINTER
870   GOSUB 6800: REM SUBJECTS DATA TO DISK
880   GOSUB 6700: REM ANY MORE SUBJECTS?
898   GOTO 530: REM LOOP BACK TO "RUN"
899 REM END OF LOOP "RUN"
900 REM EXIT TO DOS:
910 INPUT"EXIT TO DOS (Y/N)";K$
920 K$=LEFT$(K$,1): IF (K$="Y" OR K$="y") THEN CMD"S"
999 END:REM**********************
1000 GOTO 5460: REM RECOVERY FROM PRINTER HANG-UP
1999 END:REM**********************
2000 REM SUBROUTINE TO WRITE OR ERASE THE CURSOR
2010 REM INPUT IS ROW, COL, RW$ AND LW$
2020 REM ROW, COL ARE ROW AND COLUMN OF POSITION
2030 REM RW$ IS THE CURSOR (OR BLANK) TO WRITE AT RIGHT OF LOCATION
```

```
2040 REM LW$ IS THE CURSOR (OR BLANK) TO WRITE AT LEFT OF LOCATION
2050 PRINT@SCR(ROW,COL)-WIDTH,LW$;
2060 PRINT@SCR(ROW,COL)+WIDTH,RW$;
2070 RETURN
2799 END:REM**********************
2800 REM FAST CURSOR RIGHT ROUTINE
2810 SCR=SCR(ROW,COL)+15360-WIDTH
2820 POKE SCR,SPACE: REM ERASE LEFT CURSOR
2830 POKE SCR+2*WIDTH,SPACE: REM ERASE RIGHT CURSOR
2840 IF COL=CMAX THEN COL=1 ELSE COL=COL+1
2850 SCR=SCR(ROW,COL)+15360-WIDTH
2860 POKE SCR,LCUR: REM WRITE LEFT CURSOR
2870 POKE SCR+2*WIDTH,RCUR: REM WRITE RIGHT CURSOR
2880 RETURN
2999 END:REM**********************
3000 REM SUBROUTINE TO ERASE THE CURSOR
3020 LW$=" ": RW$=" "
3030 GOSUB 2000
3040 RETURN
3099 END:REM**********************
3100 REM SUBROUTINE TO WRITE THE CURSOR AT NEW LOCATION
3110 LW$=LCUR$: RW$=RCUR$
3120 GOSUB 2000
3130 RETURN
3199 END:REM**********************
3200 REM SUBROUTINE TO MOVE CURSOR DOWN (WRAP AROUND AT BOTTOM)
3210 GOSUB 3000  :REM ERASE OLD CURSOR
3220 IF ROW=RMAX THEN ROW=1 ELSE ROW=ROW+1
3230 GOSUB 3100
3240 RETURN
3299 END:REM**********************
3300 REM CURSOR RIGHT
3310 GOSUB 3000  :REM ERASE OLD CURSOR
3320 IF COL=CMAX THEN COL=1 ELSE COL=COL+1
3330 GOSUB 3100
3340 RETURN
3399 END:REM**********************
3400 REM CURSOR UP
3410 GOSUB 3000
3420 IF ROW=1 THEN ROW=RMAX ELSE ROW=ROW-1
3430 GOSUB 3100
3440 RETURN
3499 END:REM**********************
3500 REM CURSOR LEFT
3510 GOSUB 3000
3520 IF COL=1 THEN COL=CMAX ELSE COL=COL-1
3530 GOSUB 3100
3540 RETURN
3599 END:REM**********************
3600 REM DISPLAY SELECTED ITEM
3610 PRINT@ TLIN+36,CHR$( ENTRY (ROW,COL));
3620 RETURN
4499 END:REM**********************
4500 SBJCHANGE=-1
4510 PRINT:PRINT"MAXIMUM NO. OF TRIALS (";NMAX;")"
4515 PRINT"HAS BEEN REACHED."
4520 PRINT:PRINT"Press <SPACE> to continue"
4530 K$="":K$=INKEY$:IF K$="" THEN GOTO 4530
4540 IF K$<>SPACE$ THEN GOTO 4530
4550 RETURN
4599 END:REM**********************
4600 REM DOS ERROR DISPLAY
```

```
4601 EC=ERR/2+1: REM ERROR CODE
4602 PRINT:REM :PRINT"ERR=";ERR,"EC=";EC
4605 IF EC=54 THEN PRINT"FILE NOT FOUND": GOTO 4680
4610 IF EC=58 THEN PRINT"DISK I/O ERROR": GOTO 4680
4620 IF EC=62 THEN PRINT"DISK FULL": GOTO 4680
4630 IF EC=65 THEN PRINT"BAD FILENAME": GOTO 4680
4640 IF EC=68 THEN PRINT"TOO MANY FILES ON DISK": GOTO 4680
4650 IF EC=69 THEN PRINT"DISK IS WRITE PROTECTED": GOTO 4680
4660 IF EC=70 THEN PRINT"FILE ACCESS DENIED":GOTO4680
4670 PRINT"MISCELLANEOUS DISK ERROR"
4680 CMD"E": REM NEWDOS DISPLAY OF DISK ERROR
4690 RETURN
4699 END:REM*********************
4700 REM SUBROUTINE TO CHOOSE FROM REMAINING POOL
4710 REM ON ENTRY:
4720 REM     CHOICE=NO. OF UNASSIGNED ITEMS
4730 REM     TAKEN(XY)=ASSIGNMENT ARRAY;
4740 REM                =0 IF XY NOT ASSIGNED
4750 REM                =-1 IF XY ASSIGNED
4760 REM ON EXIT:
4770 REM     CHOICE=CHOICE-1
4780 REM     XY IS INDEX OF CHOSEN ITEM
4790 REM     TAKEN(XY)= -1 FOR CHOSEN XY
4800 IF CHOICE=1 THEN X=1: GOTO 4830: REM NOT MUCH CHOICE
4810     X=RND(CHOICE): REM COUNT TO NEXT UNASSIGNED ITEM
4830 XY=0
4840 FOR XX=1 TO X
4850   XY=XY+1
4855   REM SKIP OVER ASSIGNED ITEMS AND BUMP INDEX:
4860   IF TAKEN(XY) THEN XY=XY+1: GOTO 4860
4870 NEXT XX
4880 TAKEN(XY)=-1: REM FLAG NEWLY ASSIGNED ITEM
4885 CHOICE=CHOICE-1: REM HOUSEKEEPING
4890 RETURN
4899 END:REM*********************
4900 REM CLEAR ALL CHOICES
4910 FOR XY=1 TO LMAX
4920   TAKEN(XY)=0: REM ALL LETTERS AVAILABLE FOR SELECTION
4930 NEXT XY
4940 CHOICE=LMAX: REM AND NO. OF CHOICES IS MAXIMUM
4950 RETURN
4999 END:REM*********************
5000 CLS:IF WIDTH=2 THEN PRINTCHR$(23):REM DOUBLE WIDTH SCREEN
5020 RETURN
5099 END:REM*********************
5100 REM DISPLAY DATA ON SCREEN
5105 CLS: PRINT"     VALID TRIAL RESULTS FOR ";SUBJECT$
5110 PRINT" TRIAL #     SCORE      PASSES      RATE      TARG POS"
5115 PRINT" =======     =====      ======      ====      ========="
5120 FOR T= 1 TO TRIAL: REM CURRENT TRIAL IS LAST
5125   IF VLID(T)=0 THEN GOTO 5155
5130   PRINTUSING"######";T;
5135   PRINTUSING"+##########";SKAWR(T);
5140   PRINTUSING"##########";PASSES(T);
5145   PRINTUSING"##########.#";RATE!(T);
5150   PRINTUSING"##########";CARG(T)
5155 NEXT T
5160 PRINT:PRINT"  Press <SPACE> to continue";
5165 K$="":K$=INKEY$:IF NOT(K$=" ") THEN GOTO 5165
5170 PRINTCHR$(29);CHR$(30); : REM ERASE LINE
```

```
5175 PRINT"    CANCELLED TRIAL RESULTS FOR ";SUBJECT$
5180 PRINT" TRIAL #    SCORE     PASSES     RATE     TARG POS"
5185 PRINT" =======    =====     ======     ====     ========"
5190 IF TRIAL=NT THEN PRINT:PRINT"  NONE.":PRINT:GOTO 5250
5192   TC=0: REM NO. OF CANCELLED TRIALS DISPLAYED
5195   FOR T= 1 TO TRIAL: REM CURRENT TRIAL IS LAST
5200     IF VLID(T) THEN GOTO 5245
5202     TC=TC+1
5205     PRINTUSING"#####";T;
5210       IF SKAWR(T) <>999 THEN PRINTUSING "+######### "; SKAWR(T);
5215       IF SKAWR(T)=999 THEN PRINT"     ABORTED":GOTO 5235
5220     PRINTUSING"###########";PASSES(T);
5225     PRINTUSING"###########.#";RATE!(T);
5230     PRINTUSING"###########";CARG(T)
5235     IF NOT (TC/12 = INT (TC/12)) THEN GOTO 5245
5240       REM PAUSE EVERY 12TH LINE:
5242       PRINT"  Press <SPACE> to continue";
5243       K$="":K$=INKEY$:IFK$<>" " THEN GOTO 5243
5244       PRINTCHR$(29);CHR$(30); : REM CLEAR LINE
5245   NEXT T
5250 PRINT"  Press <SPACE> to continue"
5255 K$="":K$=INKEY$:IF NOT(K$=" ") THEN GOTO 5255
5260 RETURN
5299 END:REM*********************
5300 REM SEND DATA TO PRINTER
5305 PRINT: PRINT"Press <SPACE> when printer is ready."
5310 K$="":K$=INKEY$:IF NOT (K$=" ") THEN GOTO 5310
5315 PRINT:PRINT"In case of printer hang-up, press <BREAK>, then : GOTO 1000
5320 LPRINT"    VALID TRIAL RESULTS FOR ";SUBJECT$
5325 LPRINT" TRIAL #    SCORE     PASSES     RATE     TARG POS"
5330 LPRINT" =======    =====     ======     ====     ========"
5335 FOR T= 1 TO TRIAL: REM CURRENT TRIAL IS LAST
5340   IF VLID(T)=0 THEN GOTO 5370
5345   LPRINTUSING"#####";T;
5350   LPRINTUSING"+#########";SKAWR(T);
5355   LPRINTUSING"###########";PASSES(T);
5360   LPRINTUSING"###########.#";RATE!(T);
5365   LPRINTUSING"###########";CARG(T)
5370 NEXT T
5375 LPRINT
5380 LPRINT"    CANCELLED TRIAL RESULTS FOR ";SUBJECT$
5385 LPRINT" TRIAL #    SCORE     PASSES     RATE     TARG POS"
5390 LPRINT" =======    =====     ======     ====     ========"
5395 IF TRIAL=NT THEN LPRINT:LPRINT"  NONE.":GOTO 5450
5400   FOR T= 1 TO TRIAL: REM CURRENT TRIAL IS LAST
5405     IF VLID(T) THEN GOTO 5440
5410     LPRINTUSING"#####";T;
5415       IF SKAWR(T) <>999 THEN LPRINT USING" #########";SKAWR(T);
5420       IF SKAWR(T)=999 THEN LPRINT"     ABORTED":GOTO 5440
5425     LPRINTUSING"###########";PASSES(T);
5430     LPRINTUSING"###########.#";RATE!(T);
5435     LPRINTUSING"###########";CARG(T)
5440   NEXT T
5442 LPRINT:LPRINT: REM SKIP A COUPLE OF LINES
5445 PRINT:PRINT"PRINTING COMPLETE."
5450 PRINT"  Press <SPACE> to continue"
5455 K$="":K$=INKEY$:IF NOT(K$=" ") THEN GOTO 5455
5460 RETURN
5599 END:REM*********************
5600 GOSUB 5000: REM CLEAR SCREEN
5605 FOR C=1 TO CMAX
5610    FOR R=1 TO RMAX
```

```
5615     PRINT@ SCR (R,C),CHR$( ENTRY(R,C) );
5620     NEXT R
5625 NEXT C
5630 RETURN
5699 END:REM**********************
5700 REM DISPLAY OF DATA TO SCREEN OR PRINTER
5705 CLS: PRINT@64*5,"THIS SUBJECT'S SCREENING IS NOW COMPLETE."
5715 PRINT:PRINT"Press <P> to print data on external printer."
5717 PRINT"Press <D> to display data on CRT screen."
5720 PRINT"Press <B> for both printer and CRT displays."
5725 PRINT:PRINT"Press <SPACE> to proceed";
5727 PRINT" (Neither display nor print)."
5730 K$="":K$=INKEY$:IF K$="" THEN GOTO 5730
5735    IF K$=" " THEN GOTO 5765: REM EXIT IF <SPACE>
5740    IF (K$="D" OR K$="d")THEN GOSUB 5100: GOTO 5760
5745    IF (K$="P" OR K$="p") THEN GOSUB 5300: GOTO 5760
5750    IF(K$="B" OR K$="b")THENGOSUB 5100:GOSUB 5300:GOTO 5760
5755    GOTO 5730: REM IMPROPER RESPONSE
5760 CLS:PRINT@64*5," ":GOTO 5715: REM RE-OFFER CHOICES
5765 RETURN
5999 END:REM**********************
6000 GOSUB 5000: REM CLEAR SCREEN
6010 PRINT@64*5,"RANDOMIZING TARGET ARRAY."
6020 GOSUB 4900: REM CLEAR ALL CHOICES
6030 FOR C=1 TO CMAX
6040     FOR R=1 TO RMAX
6050     GOSUB 4700: REM GET AN UNUSED INDEX XY
6060     ENTRY (R,C)= ASC(LEGAL$(XY)) :REM ONE OF THE LEGAL CHARS
6070     IF CHOICE=0 THEN GOSUB 4900: REM RESET IF ALL CHOSEN
6080     NEXT R
6090 NEXT C
6100 RETURN
6199 END:REM**********************
6200 REM INFORMATION LINE
6210 PRINT@ILIN,"T#";TRIAL;"  S: ";SUBJECT$;
6220 RETURN
6399 END:REM**********************
6400 REM DISPLAY TARGET LETTER IN A BOX
6405 PRINT@TLIN-64+28,CHR$(156);
6407 PRINTCHR$(140);CHR$(172):  REM TOP LINE OF BOX
6410 PRINT@TLIN+28,CHR$(149);TARG$;CHR$(170)
6415 PRINT@TLIN+64+28,STRING$(3,131);: REM BOTTOM LINE
6420 RETURN
6699 END:REM**********************
6700 CLS
6710 PRINT@64*5,"Press <SPACE> to proceed to next subject."
6720 PRINT:PRINT"Press <ENTER> if there are no more subjects to be screened."
6730 K$="":K$=INKEY$:IF K$="" THEN GOTO 6730
6740 IF K$=" " THEN GOTO 6780: REM IF <SPACE> CONTINUE LOOP
6750 IF NOT (K$=CHR$(13)) THEN GOTO 6730: REM IF <ENTER> DO:
6760   SUBJFIN=-1: REM FINISHED WITH ALL SUBJECTS
6770   GOTO 6780
6780 RETURN
6799 END:REM**********************
6800 CLS:PRINT:PRINT:PRINT"When ready to write data for ";SUBJECT$
6805 PRINT"in disk file:  ";FSPEC$;",";"  press <SPACE>"
6815 K$="":K$=INKEY$:IFK$<>" " THEN GOTO 6815
6820 ON ERROR GOTO 6900
6822 OPEN"I",1,FSPEC$:CLOSE 1: REM VERIFY FILE EXISTS AND READY
6825 OPEN "E",1,FSPEC$
6827 REM LEADING 0, SUBJECT, TOTAL NO.OF TRIALS,
6828 REM NO. OF VALID TRIALS, CHOSEN, ACCURATE
6830 PRINT#1,0;SUBJECT$;",";TRIAL;NT;XCHOSEN;SACCURATE
```

```
6835 FOR T=1 TO TRIAL: REM CURRENT TRIAL IS MAXIMUM
6840   PRINT#1,T;SKAWR(T);PASSES(T);RATE!(T);CARG(T);VLID(T)
6845 NEXT T
6850 CLOSE 1
6855 ON ERROR GOTO 0
6860 RETURN
6899 END:REM*********************
6900 GOSUB 4600: REM DISPLAY DOS ERROR
6905 RESUME 6910
6910 ON ERROR GOTO 0
6915 PRINT:PRINT"To retry file ";FSPEC$;" press <R>,"
6920 PRINT"To try another file press <F>."
6925 K$="":K$=INKEY$:IFK$="" THEN GOTO 6925
6930 IF (K$="R" OR K$="r")THEN GOTO 6900
6935 IF (K$="F" OR K$="f") THEN GOSUB 8800: GOTO 6800
6940 GOTO 6925
7099 END:REM*********************
7100 REM COMPUTATION OF SUBJECT'S ACCURACY THE ALGORITHM IS:
7105 REM   LET NT BE THE NUMBER OF VALID TRIALS
7110 REM   LET N0 BE THE NUMBER OF 0 SCORES (NO ERROR)
7115 REM   LET N1 BE THE NUMBER OF 1 SCORES (+ OR - 1 ERROR)
7120 REM   IF NT=3 THEN
7125 REM     IF N0=3 THEN TOO ACCURATE, EXIT.
7130 REM     IF N1=3 THEN CHOSEN FOR STUDY, EXIT.
7135 REM     ELSE DO MORE TRIALS.
7140 REM   IF NT=4 THEN
7145 REM     IF N1=3 THEN CHOSEN FOR STUDY, EXIT.
7150 REM     ELSE DO MORE TRIALS.
7155 REM   IF NT=5 THEN
7160 REM     IF N1=3 THEN CHOSEN FOR STUDY, EXIT.
7165 REM     ELSE DO MORE TRIALS.
7170 REM   IF NT=6 THEN
7175 REM     IF N0=5 THEN TOO ACCURATE, EXIT.
7180 REM     IF (N0+N1 >= 3 AND N1 >=2) THEN CHOSEN, EXIT.
7185 REM     ELSE NOT CHOSEN, EXIT.
7190 REM
7195 NT=NT+1: REM UPDATE NO. OF VALID TRIALS
7200 IF SKAWR=0 THEN N0=N0+1
7205 IF (SKAWR=1 OR SKAWR=-1) THEN N1=N1+1
7210 IF N1=3 THEN GOTO 7300: REM CHOSEN
7212 REM TOO ACCURATE?:
7215 IF ((NT=3 AND N0=3) OR (NT=6 AND N0=5)) THEN GOTO 7320
7220 IF (NT < 6) THEN GOTO 7360: REM MORE TRIALS
7230 REM IF NO. OF TRIALS=6 FORCE DECISION:
7240   IF (N1 >= 2  AND  N0 >=1) THEN GOTO 7300: REM CHOSEN
7250   GOTO 7340: REM NOT CHOSEN, NOT ACCURATE, END OF TRIALS
7300 REM HERE IF CHOSEN
7310 XCHOSEN=-1: GOTO 7340
7320 REM HERE IF TOO ACCURATE
7330 SACCURATE=-1: GOTO 7340
7340 SBJCHANGE=-1: REM SUBJECT COMPLETE
7360 RETURN
7399 END:REM*********************
7400 REM TEMPORARY STORAGE OF DATA
7405 VLID(TRIAL)=VLID: REM IS TRIAL VALID?
7410 CARG(TRIAL)=CARG: REM COLUMN OF TARGET
7420 SKAWR(TRIAL)=SKAWR: REM DISTANCE OF SELECTION (-5 TO +6)
7430 PASSES(TRIAL)=PASSES: REM HOW MANY WRAP AROUNDS?
7440 RATE!(TRIAL)=RATE!: REM SCAN RATE
7450 RETURN
7499 END:REM*********************
```

```
7500 REM CHOICE OF SBJCHANGE IN CASE OF TRIAL 'ABORT" OR IGNORE
7510 PRINT@CLIN,"Press <SPACE> for next trial,"
7520 PRINT"       <ENTER> to change subject.";
7530 K$="":K$=INKEY$:IFK$="" THEN GOTO 7530
7540 IF K$=" " THEN GOTO 7590: REM EXIT IF <SPACE>
7550 IF NOT (K$=CHR$(13)) THEN GOTO 7530: REM IF <ENTER> DO:
7560   PRINT@CLIN,"WARNING!!! THIS SUBJECT'S DATA"
7565   PRINT"         IS  * NOT *  COMPLETE!!"
7570   PRINT"Press <N> for new subject,"
7580   PRINT"       any other key to continue.          ";
7585   K$="":K$=INKEY$:IF K$="" THEN GOTO 7585
7586  PRINT@CLIN,STRING$(30," "):PRINTSTRING$(30," ")
7587  PRINTSTRING$(30," "):PRINTSTRING$(30," ");
7588   IF (K$="N" OR K$="n") THEN SBJCHANGE=-1 ELSE GOTO 7500
7590 RETURN
7599 END:REM*********************
7600 IGNAWR=0
7605 PRINT@CLIN,"Press <SPACE> if trial okay,  "
7610 PRINT"       <ENTER> if not valid,"
7615 PRINT"            or <s>ee manual.";
7620 K$="":K$=INKEY$:IF K$="" THEN GOTO 7620
7632 IF NOT (K$="s") THEN GOTO 7640: REM LOWER CASE s ONLY! DO:
7633   REM DISPLAY SKAWR ABOVE INFO LINE
7634   PRINT@ CLIN-64*4,"PASSES=";PASSES;"  SCORE=";
7635   PRINTUSING"+##";SKAWR;
7640 IF NOT (K$=CHR$(13)) THEN GOTO 7699
7650   PRINT@CLIN,"Press <I> to ignore trial,   "
7660   PRINT    "any other key to continue. ";ENTER$;CHR$(30);
7670   K$=INKEY$:IF K$="" THEN GOTO 7670
7680   IF NOT (K$="I" OR K$="i") THEN GOTO 7600: REM TRY AGAIN
7690     IGNAWR=-1
7695     PRINT@CLIN-2*64,"TRIAL IGNORED.";
7696     GOTO 7700: REM AND EXIT
7699 IF NOT (K$=SPACE$) THEN GOTO 7620: REM LOOP
7700 RETURN: REM WITH IGNAWR=0 (SPACE) OR -1 (ENTER-CONFIRMED)
7799 END:REM*********************
7800 SLECT= ENTRY (ROW,COL): REM CHAR SELECTED (ASCII VALUE)
7805 SLECT$=CHR$(SLECT): REM AS A CHARACTER
7850 REM SEARCH FOR SLECT$ FROM TARG$
7860 REM FIRST IN FORWARD DIRECTION:
7870 FOR C=0 TO CMAX/2 STEP 1
7880   CX=CARG+C
7890   IF CX>CMAX THEN CX=CX-CMAX
7900   IF SLECT= ENTRY (ROW,CX) THEN SKAWR=C
7905 REMPRINT"C=";C,"CX=";CX
7910 NEXT C
7920 REM NOW SCAN REVERSE DIRECTION:
7930 FOR C=-1 TO -CMAX/2+1 STEP -1
7940   CX=CARG+C
7950   IF CX<1 THEN CX=CX+CMAX
7960   IF SLECT= ENTRY (ROW,CX) THEN SKAWR=C
7965 REMPRINT"C=";C,"CX=";CX  :REM <-- FOR DEBUGGING
7970 NEXT C
7995 RETURN
7999 END:REM*********************
8000 REM SUBROUTINE TO DRIVE CURSOR AND CHECK INPUTS
8010 RATE=INT(RATE!):TMAX=SECND(RATE)
8040 REM UNTIL INPUT DO:
8050   GOSUB 8300: REM CHECK INPUTS TMAX ITERATIONS
8060   IF K$<>"" THEN GOTO 8110: REM QUIT IF ABORT OR SELECT
8070   REM ELSE DO:
```

```
8080      GOSUB 2800: REM DRIVE CURSOR RIGHT
8090      IF COL=1 THEN PASSES=PASSES+1
8100    GOTO 8050: REM AND LOOP
8110 KK$=INKEY$: REM MUST RESET INKEY$ BEFORE RETURN
8120 RETURN
8299 END:REM*********************
8300 REM CHECK INPUTS TMAX ITERATIONS, RET ABORT OR SELECT
8320 FOR T=1 TO TMAX
8325   REM IF <ENTER>, THEN ABORT
8330   IF PEEK(14400)=1 THEN K$="ABORT": GOTO 8355
8335   REM CHECK FOR SELECTION (VIA SWITCH)
8340   REM IF <@>, THEN SELECT
8345   IF PEEK(14337)=1 THEN K$="SELECT": GOTO 8355
8350   GOTO8360: REM LOOP IF NEITHER
8355   IF (K$="ABORT" OR K$="SELECT") THEN
         T=TMAX+1: REM EXIT LOOP
8360 NEXT T
8370 RETURN
8399 END:REM*********************
8400 GOSUB 6400: REM DISPLAY TARGET CHAR
8420 ROW=1: COL=1: GOSUB 3100: REM HOME AND WRITE CURSOR
8430 RETURN
8499 END:REM*********************
8500 REM SUBROUTINE TO (OPTIONALLY) GET NEW RATE AND GO
8505 PRINT@RLIN,"RATE=";
8510 PRINTUSING"#.#";RATE!;
8515 PRINT@RLIN+WIDTH*9," <R> to alter,"
8517 PRINTSTRING$(6," ");"<SPACE> to start trial.  ";
8520 K$="":K$=INKEY$:IF K$="" THEN GOTO 8520
8522 IF NOT (K$=SPACE$ OR K$="R" OR K$="r") THEN GOTO 8520
8525 PRINT@RLIN+WIDTH*9,STRING$(15," ")
8530 IF K$=SPACE$ THEN GOTO 8595
8535   REM IF "R" THEN DO:
8540   PRINT@RLIN+WIDTH*9,"New rate?"
8542   PRINT"   (0.5 1.0 2.0 5.0) ";CHR$(95);
8545   K$="":K$=INKEY$
8550   IF NOT(K$="0" OR K$="1" OR K$="2" OR K$="5" OR K$=".")
       THEN GOTO 8545
8555   IF NOT(K$="0" OR K$=".") THEN GOTO 8580
8560     PRINT CHR$(8);"0.";CHR$(95);
8565     K$=INKEY$:IF NOT(K$="5") THEN GOTO 8565
8570     PRINT CHR$(8);K$;: K$="0.5"
8575   GOTO8585
8580   PRINT CHR$(8);K$;".0";
8585   RATE!=VAL(K$)
8590 FORXX=1TO350:NEXT: GOTO 8500: REM DELAY AND LOOP
8595 PRINT"<ENTER> aborts trial.";
8597 RETURN
8599 END:REM*********************
8600 GOSUB 4700: REM GET AN INDEX W/OUT REPLACEMENT (XY)
8610 TARG$=LEGAL$(XY)
8620 TARG=ASC(TARG$): REM USE ASCII VALUE FOR SEARCHES
8630 REM FIND COLUMN OF TARG$
8635 ROW=1: REM THIS WILL BE AN OUTER LOOP IN SWITCH/BAS
8640 FOR C=1 TO CMAX
8650   IF TARG= ENTRY (ROW,C) THEN CARG=C
8660 NEXT C
8670 RETURN
8699 END:REM*********************
8700 CLS
8710 PRINT:PRINT:PRINT
```

```
8720 SUBJECT$=""
8725 ZZ=FRE(SUBJECT$): REM GARBAGE COLLECTION
8730 PRINT"Enter the identifier for the next subject. Do not use commas."
8735 PRINT"(Maximum length = 22 characters)"
8736 PRINT:PRINT"                                        111111111 22"
8737       PRINT"                              123456789.123456789.12"
8740 INPUT"Subject identifier";SUBJECT$
8745 SUBJECT$=LEFT$(SUBJECT$,22): REM TRUNCATE
8750 PRINT:PRINT:PRINT"Press <SPACE> if";STRING$(2,13);
8755 PRINTSUBJECT$;STRING$(2,13);"is okay, any other key if not."
8760 K$=""
8770 K$=INKEY$:IF K$="" THEN GOTO 8770
8780 IF NOT (K$=SPACE$)THEN GOTO 8700
8782 REM IF NOT, TRY AGAIN, ELSE RESET COUNTERS:
8783 REM NT=NO. OF VALID TRIALS, NO=NO. OF 0 ERRORS,
8784 REM N1=NO. OF +-1 ERRORS.
8785 TRIAL=0: XCHOSEN=0: SACCURATE=0: NT=0: NO=0: N1=0
8790 RETURN
8799 END:REM*********************
8800 CLS
8810 PRINT:PRINT:PRINT
8840 PRINT"Enter name of disk file to which the data"
8845 PRINT"   from this session is to be added"
8850 PRINT:PRINT"or press <SPACE> if:  ";
8855 PRINT FSPEC$;"  is okay."
8860 PRINT:PRINT"File name? ";
8862 K$="":K$=INKEY$:IF K$="" THEN GOTO 8862
8864 IF K$=SPACE$ THEN GOTO 8872: REM IF NOT <SPACE> DO:
8866   FSPEC$=K$: REM GET FIRST CHAR
8868   PRINTFSPEC$;: REM AND ECHO IT
8870   LINE INPUT K$: REM AND GET REST OF NEW FILESPEC
8871   FSPEC$=FSPEC$+K$
8872 ON ERROR GOTO 8900: REM ATTEMPT TO OPEN EXISTING FILE
8875 OPEN "I",1,FSPEC$: REM VERIFY FIRST LINES OF FILE OK
8880 LINE INPUT#1,K1$: LINE INPUT#1,K2$: LINE INPUT#1,K3$
8881 CLOSE 1
8882 ON ERROR GOTO 0: REM DISABLE ERROR TRAPPING
8885 PRINT:PRINT"THESE ARE THE FIRST 3 LINES IN FILE:  ";FSPEC$
8886 PRINT:PRINTK1$:PRINTK2$:PRINTK3$
8890 PRINT:PRINT"Press <SPACE> if this is okay, any other key if not."
8895 K$="":K$=INKEY$:IF K$="" THEN GOTO 8895
8897 IFK$<>" " THEN GOTO 8800: REM NOT PROPER FILE
8898 RETURN: REM PROPER FILE HAS BEEN VERIFIED
8899 END:REM*********************
8900 REM ERROR HANDLING FOR INITIAL OPEN
8905 GOSUB 4600: REM DISPLAY DOS ERROR
8907 RESUME 8908
8908 ON ERROR GOTO 0: REM RESTOR ERROR HANDLING
8910 IF EC<>54 THEN GOTO 8947: REM IF NOT FOUND DO:
8915   PRINT:PRINTFSPEC$;" NOT FOUND.":PRINT"Press <C> to create new file,
8920   PRINT"      any other key to continue."
8925   K$="":K$=INKEY$:IFK$="" THEN GOTO 8925
8930   IFNOT(K$="C" OR K$="c")THEN GOTO8995:REMCREATE NEW FILE:
8932     ON ERROR GOTO 8900
8935     OPEN"O",1,FSPEC$
8940     PRINT#1,"CHILDREN'S HOSPITAL AT STANFORD PROJECT. SCREENING DATA."
8942     PRINT#1,"IDENT: 0; SUBJ ID; TOT. TRIALS; VALID TRIALS; CHOSEN?; ACCUR?"
8943     PRINT#1,"DATA: TRIAL; SCORE; PASSES; RATE; TARG POS; VALID?"
8945     CLOSE 1: ON ERROR GOTO 0:  GOTO 8995
8947 PRINT"Press <SPACE > to continue"
8950 K$="":K$=INKEY$:IFK$<>" " THEN GOTO 8950
8995 GOTO 8800
8999 END:REM*********************
9000 CLS:PRINT@5*64,"  INITIALIZING."
9002 DEFINT A-Z: REM SINGLE AND STRING MUST BE EXPLICIT
```



64

```
9005 WIDTH=2: REM 1=SINGLE, 2=DOUBLE
9007 RCUR=132
9008 LCUR=136
9010 RCUR$= CHR$(RCUR)
9015 LCUR$= CHR$(LCUR)
9017 SPACE$=" ": ENTER$=CHR$(13)
9018 SPACE=ASC(SPACE$): ENTER=ASC(ENTER$)
9020 SECND!=28: REM 1 SEC IN TIMING LOOP CF. SECND(RATE)
9025 DWN$=CHR$(10): UP$=CHR$(91): LFT$=CHR$(8): RGT$=CHR$(9): REM ARROW KEYS
9028 ROW=0: COL=0: SCR=0 :REM DEFINED HERE FOR QUICK ACCESS
9030 TLIN=64*1: REM LINE FOR TARGET AND SELECTION DISPLAY
9035 ILIN=64*13: REM SUBJECT ID LINE
9040 CLIN=ILIN-64*4: REM LINE FOR CHOICES (IGNORE, ABORT, ETC.)
9045 RLIN=64*14: REM RATE LINE
9048 RATE!=1.0: REM (0.5, 1.0, 2.0, 5.0)
9050 RATE=INT(RATE!): REM INDEX FOR SECND ARRAY (0,1,2,5)
9051 CARG=0: REM COLUMN OF TARGET CHAR
9052 TARG=0: REM ASCII VALUE OF TARGET CHAR
9053 SELECT=0: REM ASCII VALUE OF SELECTED CHAR
9054 VLID=-1: REM TRIAL VALID? (-1=YES)
9055 SKAWR=0: REM SCORE ON A TRIAL
9060 PASSES=0: REM NO. OF PASSES ON A TRIAL
9065 SUBJFIN=0: REM NO MORE SUBJECTS? (-1=NO MORE)
9070 SBJCHANGE=0: REM NEW SUBJECT? (-1=YES)
9072 SACCURATE=0: REM SUBJECT TOO ACCURATE? (-1=YES)
9073 XCHOSEN=0: REM SUBJECT CHOSEN FOR STUDY? (-1=YES)
9075 IGNAWR=0: REM LAST TRIAL INVALID? (-1=YES)
9076 NT=0: REM NO. OF VALID TRIALS
9077 N0=0: N1=0: REM NO. OF 0 (+-1) ERRORS
9080 CHOICE=0: REM NO. OF CHOICES LEFT IN POOL
9085 XY=0: REM INDEX OF CURRENT CHOICE
9090 FSPEC$="SCREEN/DAT": REM DEFAULT DATA FILE
9350 GOSUB 9400: REM SETUP ARRAYS
9360 RETURN
9399 END:REM**********************
9400 REM SETUP ARRAYS.  SCR(ROW,COL) IS SCREEN POSITION OF ROW AND COLUMN
9410 RMAX=1: CMAX=12:  REM ROW AND COLUMN SIZE
9420 DIM SCR(RMAX,CMAX): DIM ENTRY(RMAX,CMAX)
9430 FOR R=1 TO RMAX
9440    ROW= 2+1*R      :REM FIRST 5 LINES FOR INFORMATION
9450    FOR C=1 TO CMAX
9455       REM 2=1 CHAR + 1 SPACE.  CENTER ARRAY ON SCREEN:
9460       COL=(64/WIDTH-2*CMAX)/2+2*WIDTH*C
9470       SCR(R,C)=ROW*64+COL
9480    NEXT C
9490 NEXT R
9500 REM MAXIMUM TRIALS FOR ANY SUBJECT (INCL INVALID ONES)
9510 NMAX=25
9520 DIM CARG(NMAX): DIM PASSES(NMAX)
9530 DIM SKAWR(NMAX): DIM RATE!(NMAX)
9540 DIM VLID(NMAX)
9550 SECND(0)=SECND!*0.41: REM RATE!=0.5
9555 SECND(1)=SECND!*1.0: REM RATE!=1.0
9560 SECND(2)=SECND!*2.24: REM RATE!=2.0
9565 SECND(5)=SECND!*5.91: REM RATE!=5.0
9600 REM ONLY LEGAL CHARACTERS FOR DISPLAY
9610 LMAX=12: REM NO. OF LEGAL CHARACTERS
9615 DIM TAKEN(LMAX): REM ASSIGNMENT ARRAY
9620 DIM LEGAL$(LMAX)
9630 FOR L=1 TO LMAX
9640     READ LEGAL$(L)
9650 NEXT L
9660 RETURN
9670 DATA L,A,H,X,E,T,P,U,J,Z,S,D
```

```
490 GOSUB 8000: REM DISPLAY THIS PROGRAM'S FUNCTION
500 CLEAR 1000: GOSUB 9000: REM INITIALIZE POINTERS AND ARRAYS
520 FINFIL=0: REM 0=MORE FILES, -1=NO MORE
530 IF FINFIL THEN GOTO 900
540 REM DO UNTIL NO MORE FILES:  LOOP "FILE"
550   EOF=0: REM -1=END OF FILE 0=NOT  ** NOTE SPELLING **
560   GOSUB 8800: REM GET FILESPEC, OPEN FILE, VERIFY OK
570   GOSUB 7900: REM ALL OR SINGLE SUBJECT MODE?
580   IF NOT ALL THEN GOTO 610: REM IF ALL DO:
590     SUBJECT$="ALL SUBJECTS IN FILE"
600     CLS: GOSUB 5700: REM TYPE OF DISPLAY FOR ALL?
605     IF K$=SPACE$ THEN EOF=-1: REM IF NO DISPLAY, EXIT FILE
607     DSP$=K$: REM STORE TYPE OF DISPLAY
610   IF EOF THEN GOTO 700 :REM UNTIL EOF DO:  LOOP "SUBJECT"
620     GOSUB 7800: REM GET NEXT SUBJECT AND DATA
625     REM IF NOT ALL GET TYPE OF DISPLAY THIS SUBJECT
630     IF NOT ALL THEN GOSUB 5700: DSP$=K$
640     K$=DSP$: REM GET PERMANENT VALUE IF ALL
642     IF K$=" " THEN CLS: GOTO 650: REM IF DESIRED DO:
643       GOSUB 6000: REM FIRST DISPLAY AS PER DSP$
645       GOSUB 6100: REM REPEAT DISPLAY IF DESIRED
650     EOF=EOF(1): REM END OF FILE?
660   GOTO 610: REM END LOOP "SUBJECT"
700   GOSUB 7600: REM ANY MORE FILES? (SET FINFIL)
710 GOTO 530: REM END LOOP "FILE"
900 REM EXIT TO DOS:
910 INPUT"EXIT TO DOS (Y/N)";K$
920 K$=LEFT$(K$,1): IF (K$="Y" OR K$="y") THEN CMD"S"
999 END:REM*********************
1000 GOTO 5450: REM RECOVERY FROM PRINTER HANG-UP
4599 END:REM*********************
4600 REM DOS ERROR DISPLAY
4601 EC=ERR/2+1: REM ERROR CODE
4602 PRINT:REM :PRINT"ERR=";ERR,"EC=";EC
4605 IF EC=54 THEN PRINT"FILE NOT FOUND": GOTO 4680
4610 IF EC=58 THEN PRINT"DISK I/O ERROR": GOTO 4680
4620 IF EC=62 THEN PRINT"DISK FULL": GOTO 4680
4630 IF EC=65 THEN PRINT"BAD FILENAME": GOTO 4680
4640 IF EC=68 THEN PRINT"TOO MANY FILES ON DISK": GOTO 4680
4650 IF EC=69 THEN PRINT"DISK IS WRITE PROTECTED": GOTO 4680
4660 IF EC=70 THEN PRINT"FILE ACCESS DENIED":GOTO4680
4670 PRINT"MISCELLANEOUS DISK ERROR"
4680 CMD"E": REM NEWDOS DISPLAY OF DISK ERROR
4690 RETURN
4999 END:REM*********************
5000 CLS:IF WIDTH=2 THEN PRINTCHR$(23):REM DOUBLE WIDTH SCREEN
5020 RETURN
5099 END:REM*********************
5100 REM DISPLAY DATA ON SCREEN
5105 PRINT:PRINT"     VALID TRIAL RESULTS FOR ";SUBJECT$
5107 PRINT"     CHOSEN? --";YESNO$(XCHOSEN+1);
5108 PRINT"     TOO ACCURATE? --";YESNO$(SACCURATE+1)
5110 PRINT" TRIAL #     SCORE      PASSES      RATE       TARG POS"
5115 PRINT" =======     =====      ======      ====       ========"
5120 FOR T= 1 TO TRIAL: REM CURRENT TRIAL IS LAST
5125   IF VLID(T)=0 THEN GOTO 5155
5130   PRINTUSING"######";T;
5135   PRINTUSING"+##########";SKAWR(T);
5140   PRINTUSING"##########";PASSES(T);
5145   PRINTUSING"##########.#";RATE!(T);
5150   PRINTUSING"##########";CARG(T)
```

```
5155 NEXT T
5160 PRINT:PRINT"  Press <SPACE> to continue";
5165 K$="":K$=INKEY$:IF NOT(K$=" ") THEN GOTO 5165
5170 PRINTCHR$(29);CHR$(30); : REM ERASE LINE
5175 PRINT"    CANCELLED TRIAL RESULTS FOR ";SUBJECT$
5180 PRINT" TRIAL #     SCORE      PASSES      RATE      TARG POS"
5185 PRINT" =======     =====      ======      ====      ========"
5190 IF TRIAL=NT THEN PRINT:PRINT"  NONE.":PRINT:GOTO 5250
5192   TC=0: REM NO. OF CANCELLED TRIALS DISPLAYED
5195   FOR T= 1 TO TRIAL: REM CURRENT TRIAL IS LAST
5200     IF VLID(T) THEN GOTO 5245
5202     TC=TC+1
5205     PRINTUSING"#####";T;
5210       IF SKAWR(T) <>999 THEN PRINTUSING "+######### "; SKAWR(T);
5215       IF SKAWR(T)=999 THEN PRINT"      ABORTED":GOTO 5235
5220     PRINTUSING"###########";PASSES(T);
5225     PRINTUSING"###########.#";RATE!(T);
5230     PRINTUSING"###########";CARG(T)
5235     IF NOT (TC/12 = INT (TC/12)) THEN GOTO 5245
5240       REM PAUSE EVERY 12TH LINE:
5242       PRINT"  Press <SPACE> to continue";
5243       K$="":K$=INKEY$:IFK$<>" " THEN GOTO 5243
5244       PRINTCHR$(29);CHR$(30); : REM CLEAR LINE
5245   NEXT T
5250 RETURN
5299 END:REM**********************
5300 REM SEND DATA TO PRINTER
5305 PRINT: PRINT"Press <SPACE> when printer is ready."
5310 K$="":K$=INKEY$:IF NOT (K$=" ") THEN GOTO 5310
5315 PRINT:PRINT"In case of printer hang-up, press <BREAK>, then : GOTO 1000
5320 LPRINT"     VALID TRIAL RESULTS FOR ";SUBJECT$
5322 LPRINT"     CHOSEN? --";YESNO$(XCHOSEN+1);
5323 LPRINT"     TOO ACCURATE? --";YESNO$(SACCURATE+1)
5325 LPRINT" TRIAL #     SCORE      PASSES      RATE      TARG POS"
5330 LPRINT" =======     =====      ======      ====      ========"
5335 FOR T= 1 TO TRIAL: REM CURRENT TRIAL IS LAST
5340   IF VLID(T)=0 THEN GOTO 5370
5345   LPRINTUSING"#####";T;
5350   LPRINTUSING"+##########";SKAWR(T);
5355   LPRINTUSING"###########";PASSES(T);
5360   LPRINTUSING"###########.#";RATE!(T);
5365   LPRINTUSING"###########";CARG(T)
5370 NEXT T
5375 LPRINT
5380 LPRINT"    CANCELLED TRIAL RESULTS FOR ";SUBJECT$
5385 LPRINT" TRIAL #     SCORE      PASSES      RATE      TARG POS"
5390 LPRINT" =======     =====      ======      ====      ========"
5395 IF TRIAL=NT THEN LPRINT:LPRINT"  NONE.":GOTO 5442
5400   FOR T= 1 TO TRIAL: REM CURRENT TRIAL IS LAST
5405     IF VLID(T) THEN GOTO 5440
5410     LPRINTUSING"#####";T;
5415       IF SKAWR(T) <>999 THEN LPRINT USING" ##########";SKAWR(T);
5420       IF SKAWR(T)=999 THEN LPRINT"      ABORTED":GOTO 5440
5425     LPRINTUSING"###########";PASSES(T);
5430     LPRINTUSING"###########.#";RATE!(T);
5435     LPRINTUSING"###########";CARG(T)
5440   NEXT T
5442 LPRINT:LPRINT: REM SKIP A COUPLE OF LINES
5445 PRINT:PRINT"PRINTING COMPLETE."
5450 RETURN
5699 END:REM**********************
```

```
5700 REM GET TYPE OF DISPLAY DESIRED, RETURN IN K$
5705 PRINT@64*5,"How do you want the data presented for ";
5710 PRINTSUBJECT$;" ?"
5715 PRINT:PRINT"Press <P> to print data on external printer."
5717 PRINT"Press <D> to display data on CRT screen."
5720 PRINT"Press <B> for both printer and CRT displays."
5725 PRINT:PRINT"Press <SPACE> to proceed";
5727 PRINT" (Neither display nor print)."
5730 K$="":K$=INKEY$:IF K$="" THEN GOTO 5730
5735   IF K$=" " THEN GOTO 5790: REM EXIT IF <SPACE>
5740   IF (K$="D" OR K$="d")THEN GOTO 5790
5745   IF (K$="P" OR K$="p") THEN GOTO 5790
5750   IF(K$="B" OR K$="b")THEN GOTO 5790
5755   GOTO 5730: REM IMPROPER RESPONSE
5790 RETURN
5999 END:REM**********************
6000 REM TYPE OF DISPLAY (IN K$)
6005   IF K$=" " THEN GOTO 6050: REM EXIT IF <SPACE>
6010   IF (K$="D" OR K$="d")THEN GOSUB 5100: GOTO 6050
6020   IF (K$="P" OR K$="p") THEN GOSUB 5300: GOTO 6050
6030   IF(K$="B" OR K$="b")THENGOSUB 5100:GOSUB 5300:GOTO 6050
6050 RETURN
6099 END:REM**********************
6100 PRINT"  Press <SPACE> to continue,
6110 PRINT"  Press <R> for repeated display and/or print.";
6120 K$="":K$=INKEY$:IF K$="" THEN GOTO 6120
6130 IF K$=" " THEN GOTO 6190: REM EXIT IF SPACE
6140 IF NOT (K$="R" OR K$="r") THEN GOTO 6120
6150   CLS:GOSUB 5700: REM GET TYPE OF DISPLAY
6155  IF K$=" " THEN GOTO 6190: REM QUIT IF NO DISPLAY
6160   GOSUB 6000: REM DO IT
6170   GOTO 6100: REM AND LOOP
6190 CLS: RETURN
6699 END:REM**********************
6700 CLS
6710 PRINT@64*5,"Press <SPACE> to proceed to next subject."
6720 PRINT:PRINT"Press <ENTER> if there are no more subjects to be screened."
6730 K$="":K$=INKEY$:IF K$="" THEN GOTO 6730
6740 IF K$=" " THEN GOTO 6780: REM IF <SPACE> CONTINUE LOOP
6750 IF NOT (K$=CHR$(13)) THEN GOTO 6730: REM IF <ENTER> DO:
6760   SUBJFIN=-1: REM FINISHED WITH ALL SUBJECTS
6770   GOTO 6780
6780 RETURN
6799 END:REM**********************
6800 REM DISK ERROR HANDLING FOR INPUT FROM FILE
6805 GOSUB 4600: REM DISPLAY DOS ERROR
6810 RESUME 6815
6815 ON ERROR GOTO 0
6830 PRINT:PRINT"To retry file ";FSPEC$;" press <R>,"
6835 PRINT"To try another file press <F>."
6840 K$="":K$=INKEY$:IFK$="" THEN GOTO 6840
6845 IF (K$="R" OR K$="r")THEN GOTO 7800
6850 IF (K$="F" OR K$="f") THEN RUN 500
6855 GOTO 6840
6899 END:REM**********************
6900 REM DISK ERROR HANDLING FOR INITIAL OPEN OF FILE
6905 GOSUB 4600: REM DISPLAY DOS ERROR
6910 RESUME 6920
6920 ON ERROR GOTO 0
6940 GOTO 8805: REM PROMPT AGAIN FOR FILESPEC
7399 END:REM**********************
7400 REM TEMPORARY STORAGE OF DATA
7405 VLID(TRIAL)=VLID: REM IS TRIAL VALID?
7410 CARG(TRIAL)=CARG: REM COLUMN OF TARGET
```

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7420 SKAWR(TRIAL)=SKAWR: REM DISTANCE OF SELECTION (-5 TO +6)
7430 PASSES(TRIAL)=PASSES: REM HOW MANY WRAP AROUNDS?
7440 RATE!(TRIAL)=RATE!: REM SCAN RATE
7450 RETURN
7599 END:REM**********************
7600 CLS:PRINT:PRINT:PRINT
7602 CLOSE
7605 PRINT"END OF PROCESSING FOR FILE:    ";FSPEC$:PRINT:PRINT
7610 PRINT"Press <SPACE> to proceed to a new file.
7620 PRINT:PRINT"Press <ENTER> if you do not wish to look at any more data.
7630 K$="":K$=INKEY$:IF K$="" THEN GOTO 7630
7640 IF K$=" " THEN GOTO 7680: REM IF <SPACE> CONTINUE LOOP
7650 IF NOT (K$=ENTER$) THEN GOTO 7630: REM IF <ENTER> DO:
7660   FINFIL=-1
7670   GOTO 7680
7680 RETURN
7799 END:REM**********************
7800 REM GET SUBJECT AND DATA, DISPLAY SUBJECT
7810 ON ERROR GOTO 6800
7820 REM LEADING 0, SUBJECT, TOTAL NO.OF TRIALS,
7830 REM NO. OF VALID TRIALS, CHOSEN, ACCURATE
7840 INPUT#1,T,SUBJECT$,TRIAL,NT,XCHOSEN,SACCURATE
7850 FOR XT=1 TO TRIAL: REM CURRENT TRIAL IS MAXIMUM
7860   INPUT#1,T,SKAWR(T),PASSES(T),RATE!(T),CARG(T),VLID(T)
7870 NEXT XT
7880 ON ERROR GOTO 0: REM DISABLE ERROR TRAPPING
7882 CLS:PRINT"SUBJECT: ";SUBJECT$
7885 PRINT" CHOSEN? --";YESNO$(XCHOSEN+1);
7887 PRINT"  TOO ACCURATE? --";YESNO$(SACCURATE+1)
7890 RETURN
7899 END:REM**********************
7900 CLS: PRINT:PRINT:PRINT
7910 PRINT"Press <SPACE> if you want to decide for each subject
7920 PRINT"    in the file, whether to display and/or print the data.
7930 PRINT:PRINT"Press <A> if you want ALL the subjects in the file
7940 PRINT"    to be displayed and/or printed in the same way.
7950 K$="":K$=INKEY$:IF K$="" THEN GOTO 7950
7960 IF K$=" " THEN ALL=0: GOTO 7990
7970 IF (K$="A" OR K$="a") THEN ALL=-1: GOTO 7990
7980 GOTO 7950: REM INVALID RESPONSE
7990 CLS
7995 RETURN
7999 END:REM**********************
8000 CLS
8010 PRINT"The purpose of this program is to display and/or print
8020 PRINT"    data stored by the program SCREEN/BAS.
8030 PRINT:PRINT"This program will prompt you for the name of the
8040 PRINT"    file in which the data was stored by SCREEN/BAS.
8080 PRINT:PRINT"After you verify that the correct file has been opened,
8085 PRINT"    you will be given the option of displaying the data
8090 PRINT"    for ALL of the subjects in the file in the same manner,
8100 PRINT"    or of deciding for each individual subject in the file,
8110 PRINT"    whether or not (and how) you want the data displayed.
8130 PRINT:PRINT"You will be able to repeat the display of any data
8140 PRINT"    that is presented, as many times as you wish.
8150 PRINT:PRINT"Press <SPACE> when you are ready to begin.";
8160 K$="":K$=INKEY$:IF K$<>" " THEN GOTO 8160
8170 RETURN
8799 END:REM**********************
8800 CLS
```

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8805 CLOSE: REM MUST CLOSE BEFORE OPENING A NEW ONE
8810 PRINT:PRINT:PRINT
8840 PRINT"Enter name of disk file from which the data"
8845 PRINT"   to be displayed and/or printed is to be taken"
8850 PRINT:PRINT"or press <SPACE> if:  ";
8855 PRINT FSPEC$;"  is okay."
8860 PRINT:PRINT"File name? ";
8862 K$="":K$=INKEY$:IF K$="" THEN GOTO 8862
8864 IF K$=SPACE$ THEN GOTO 8872: REM IF NOT <SPACE> DO:
8866   FSPEC$=K$: REM GET FIRST CHAR
8868   PRINTFSPEC$;: REM AND ECHO IT
8870   LINE INPUT K$: REM AND GET REST OF NEW FILESPEC
8871   FSPEC$=FSPEC$+K$
8872 ON ERROR GOTO 6900: REM ATTEMPT TO OPEN EXISTING FILE
8875 OPEN "I",1,FSPEC$: REM VERIFY FIRST LINES OF FILE OK
8880 LINE INPUT#1,K1$: LINE INPUT#1,K2$: LINE INPUT#1,K3$
8882 ON ERROR GOTO 0: REM DISABLE ERROR TRAPPING
8885 PRINT:PRINT"THESE ARE THE FIRST 3 LINES IN FILE:  ";FSPEC$
8886 PRINT:PRINTK1$:PRINTK2$:PRINTK3$
8890 PRINT:PRINT"Press <SPACE> if this is okay, any other key if not."
8895 K$="":K$=INKEY$:IF K$="" THEN GOTO 8895
8897 IFK$<>" " THEN GOTO 8800: REM NOT PROPER FILE
8898 RETURN: REM PROPER FILE HAS BEEN VERIFIED
8999 END:REM**********
9000 CLS:PRINT@5*64,"  INITIALIZING."
9002 DEFINT A-Z: REM SINGLE AND STRING MUST BE EXPLICIT
9005 WIDTH=2: REM 1=SINGLE, 2=DOUBLE
9017 SPACE$=" ": ENTER$=CHR$(13)
9018 SPACE=ASC(SPACE$): ENTER=ASC(ENTER$)
9020 YESNO$(0)="YES": YESNO$(1)="NO "
9028 ROW=0: COL=0: SCR=0 :REM DEFINED HERE FOR QUICK ACCESS
9030 TLIN=64*1: REM LINE FOR TARGET AND SELECTION DISPLAY
9035 ILIN=64*13: REM SUBJECT ID LINE
9040 CLIN=ILIN-64*4: REM LINE FOR CHOICES (IGNORE, ABORT, ETC.)
9045 RLIN=64*14: REM RATE LINE
9048 RATE!=1.0: REM (0.5, 1.0, 2.0, 5.0)
9050 RATE=INT(RATE!): REM INDEX FOR SECND ARRAY (0,1,2,5)
9051 CARG=0: REM COLUMN OF TARGET CHAR
9052 TARG=0: REM ASCII VALUE OF TARGET CHAR
9053 SELECT=0: REM ASCII VALUE OF SELECTED CHAR
9054 VLID=-1: REM TRIAL VALID? (-1=YES)
9055 SKAWR=0: REM SCORE ON A TRIAL
9060 PASSES=0: REM NO. OF PASSES ON A TRIAL
9065 SUBJFIN=0: REM NO MORE SUBJECTS? (-1=NO MORE)
9070 SBJCHANGE=0: REM NEW SUBJECT? (-1=YES)
9072 SACCURATE=0: REM SUBJECT TOO ACCURATE? (-1=YES)
9073 XCHOSEN=0: REM SUBJECT CHOSEN FOR STUDY? (-1=YES)
9075 IGNAWR=0: REM LAST TRIAL INVALID? (-1=YES)
9076 NT=0: REM NO. OF VALID TRIALS
9077 N0=0: N1=0: REM NO. OF 0 (+-1) ERRORS
9080 CHOICE%=0: REM NO. OF CHOICES LEFT IN POOL
9085 XY=0: REM INDEX OF CURRENT CHOICE
9090 FSPEC$="SCREEN/DAT": REM DEFAULT DATA FILE
9350 GOSUB 9400: REM SETUP ARRAYS
9360 RETURN
9399 END:REM**********
```

```
9400 REM SETUP ARRAYS.  SCR(ROW,COL) IS SCREEN POSITION OF ROW AND COLUMN
9410 RMAX=1: CMAX=12:  REM ROW AND COLUMN SIZE
9500 REM MAXIMUM TRIALS FOR ANY SUBJECT (INCL INVALID ONES)
9510 NMAX=25
9520 DIM CARG(NMAX): DIM PASSES(NMAX)
9530 DIM SKAWR(NMAX): DIM RATE!(NMAX)
9540 DIM VLID(NMAX)
9600 REM ONLY LEGAL CHARACTERS FOR DISPLAY
9610 LMAX=12: REM NO. OF LEGAL CHARACTERS
9615 DIM TAKEN(LMAX): REM ASSIGNMENT ARRAY
9660 RETURN
9670 DATA L,A,H,X,E,T,P,U,J,Z,S,D
```